AUTO-CARS

.AUTO-CARS.

CARS, TRAMCARS, AND SMALL CARS

BY

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TRANSLATED FROM THE FRENCH
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WITH PREFACE
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PREFACE

(TO THE FRENCH EDITION)

The interest taken in the new industry of road locomotion and the development it is acquiring in France impels me to congratulate you on the task you have undertaken, and though, notwithstanding your request, I do not intend to write a preface, I cannot refrain from the pleasure of testifying to the opportuneness and value of your interesting work.

This industry, which a few years back was but in its experimental stage, has now become a most important national one, which is due entirely to the results obtained by French manufacturers.

To spread the knowledge of these results and to instil a desire of adopting this new and fruitful application of mechanics to road locomotion is indeed useful work.

You have fulfilled these aims by writing your book, and no doubt your readers will feel the same pleasure as myself in perusing the second part, dealing historically and descriptively with our carriages of the future.

Theorists and scientists will find in the first part scientific information, technical details, and the laws that govern this new industry.

Your book will certainly be well received by the members of the *Automobile Club of France*, who are all watching with the greatest interest the exciting struggle between petroleum, steam, gas, and electricity, vying with each other for the honour of serving us.

Those of your readers who are not so well acquainted with these matters will be able to learn the difference between the various systems, and will wish to avail themselves of the pleasures of auto-car travelling, and will become, thanks to you, fervent adepts of the new system of road locomotion.

Believe me, dear Mr. Farman,

Yours &c.

BARON DE ZUYLEN DE NYEVELT,

President of the Automobile Club of France.

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AUTO-CARS

CHAPTER I

INTRODUCTION

ALTHOUGH still in its infancy, the auto-car industry has lately made such gigantic strides that it would be impossible to deal exhaustively with it in this little book.

Electricity, steam, compressed air, and last of all petroleum having each in turn been applied to the solution of this problem, we ought, to deal thoroughly with the subject, first to discuss the sciences of electricity, thermo-dynamics, and chemistry, and then go into the question of mechanics and its special application to the sources of energy with which we have to deal, a process entirely beyond the scope of the present work.

We will therefore merely touch upon steam, electrical, compressed-air, and other motors, giving, however, a more detailed description of petroleum motors, which, in our estimation, seem to have a brilliant future before them.

At the outset, however, we think it advisable to state the well-known fundamental laws of the thermo-dynamics of perfect gases, as these laws will be constantly referred to in this book.

We will assume that we are dealing with gases which obey Boyle's and Gay-Lussac's laws. Although practically no known gas obeys these two laws exactly, the discrepancy is so slight that we are easily able, by means of formulæ deduced

from these two hypotheses, to foresee what will take place in our motors.

Boyle's Law.—Boyle's or Mariotte's law is expressed by the following equation :—

$$pv = p_1 v_1 = C,$$

which means that the volume of a gas is inversely proportional to the pressure to which it is subjected. In other words, we know from Boyle's law that if we double the pressure of a gas whose volume is one litre at atmospheric pressure we halve that volume.

Gay-Lussac's Law.—This law tells us that at constant pressure the volume of a gas varies with the temperature, the increase being in proportion to the change of temperature and the volume of the gas at zero.

Let a represent the increase of volume per unit volume of the gas per degree of temperature.

Then, if the gas is raised from a temperature t to a higher temperature t', the increase of volume will be represented by

$$\triangle V = a(t' - t) V,$$

so that the volume V' of the gas at t' degrees at a constant temperature p will equal

$$V' = V + \triangle V = V + a(t' - t) V.$$

By making $t = o$, then

$$V' = V_0 + a V_0 t',$$

or

$$V' = V_0 (1 + at'),$$

which is the equation expressing Gay-Lussac's law.

The value of a has been found experimentally to be equal to $\frac{1}{273}$, and is called the coefficient of expansion of a gas.

Assuming this coefficient to be a constant, we easily arrive at a notion of what is meant by the term *absolute temperature.* Let us take, for instance, a volume V of gas at a temperature of

0° centigrade, and then lower the temperature to $-273°$ below 0°.

According to Gay-Lussac's law the volume becomes

$$V' = V - V\alpha t,$$

or, by substituting the values of α and t,

$$V' = V(1 - \frac{1}{273} \times 273) = 0.$$

This temperature of $-273°$, at which gases would, so to speak, shrink into nothing, is called *absolute zero*, and all temperatures which are counted from this point are known as *absolute temperatures.* In this work we shall designate all such temperatures by capital letters, and ordinary centigrade temperatures by small letters.

The relation between absolute temperature and ordinary centigrade temperature is expressed by the equation

$$T = t + 273.$$

By combining the laws of Boyle and Gay-Lussac we obtain an equation which enables us to express a simultaneous change of pressure and temperature.

Let v_0 represent the volume of a gas at a pressure p_0 and temperature t_0, and v_1 its volume at a pressure p_1 and temperature t_1.

Considering the change of temperature alone by supposing the pressure p_0 to be constant, we find from Gay-Lussac's law that

(1) $$v' = v_0\,[1 + \alpha(t_1 - t_0)]\,;\ (p_0, v', t_1).$$

Now by varying the pressure and considering the temperature t_1 as a constant, we find from Boyle's law that

(2) $$v_1 = \frac{v' p_0}{p_1}.$$

A combination of equations (1) and (2) gives

$$p_1 v_1 = v_0 p_0\,[1 + \alpha(t_1 - t_0)].$$

And if $t_0 = 0°$, then

(3) $$p_1 v_1 = v_0 p_0 (1 + a t_1),$$

which is the fundamental equation between the volume, pressure, and temperature of a perfect gas.

If the temperature be kept constant and the pressure varied, the volume will change in consequence, and this change can be represented graphically by a hyperbolic curve which is called an *isothermal* line, there being a different isothermal line for each temperature, as shown in Fig. 1.

Things are different, however, if the gas under consideration is enclosed in a covering which is a non-conductor of heat. By varying the volume of the gas we vary its pressure and temperature simultaneously, and the curve that we obtain by setting off the pressures as ordinates and the volumes as abscissæ is known as *adiabatic* or *isentropic*; that is, of constant entropy.

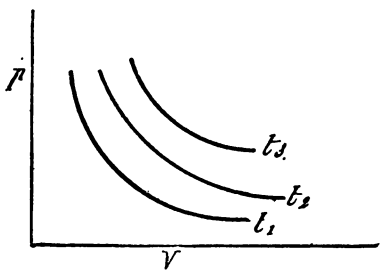


Fig. 1.

What is meant by the entropy of a gas?

This is rather difficult to define correctly without having recourse to long calculations.

We may, however, say that the *entropy* has the same relation to heat as the weight of a body has to the *potential energy* it possesses through being raised. Let us consider, for instance, a body of weight P kg. situated at a height above ground of H metres; the *potential energy* E which that body can furnish is represented by $E = P \times H$ kilogrammetres, and this energy will decrease by $\frac{E}{H} = P^{\mathrm{kgm}}$ per metre of fall.

The weight of a body, therefore, measures its decrease of potential energy per metre of fall. Similarly, we may say that the term *thermal weight* expresses the loss of thermal energy per degree of fall in temperature, the latter being analogous to the height in the former case, *i.e.* representing the intensity of the force.

If, therefore, a gas has an energy E or $(A\,E)$ calories owing to its absolute temperature T, it will evidently lose energy equal to $\frac{AE}{T}$ per degree of fall in temperature. We can therefore call $\frac{AE}{T}$ the *thermal weight* of the gas under consideration. This quotient will remain constant so long as heat is neither given to nor taken from the gas.

The thermal weight is no other than the *entropy*, whence the name of *isentropic* line given to the curve which represents the transformations effected without gain or loss of heat.

If you add a quantity of heat dq at a temperature T to a gas, you increase its entropy or thermal weight by an amount $\frac{dq}{T}$. On giving heat and raising the temperature from t_1 to t_2, the increase of entropy will be expressed by the function

$$\int_{t_1}^{t_2} \frac{dq}{T}$$

Fig. 2 represents a series of isentropic lines cutting isothermal ones.

With the exception of electrical motors, all those we shall examine are worked by an elastic fluid, either gas or steam.

While undergoing a certain series of transformations, which is termed a cycle, these gases, enclosed in a cylinder, impart dynamic force to a piston which in its turn transmits that force to the working shaft. In considering the theory of the motors we have to examine we shall always be obliged to show, by means of isothermal and adiabatic lines, the cycle

undergone by the gases, although this is not really what happens. It is impossible to obtain in any motor a transformation at an absolutely constant temperature without having an infinitely powerful source of heat at our disposal.

It is equally impossible, notwithstanding lagging, jackets, and the various methods of covering that have been tried, to obtain a cylinder which is an absolute non-conductor of heat, so that a perfect adiabatic transformation has never yet been accomplished.

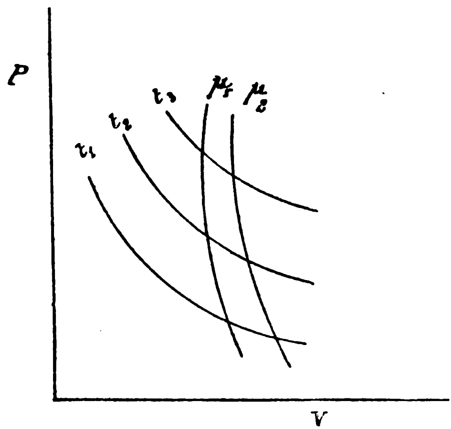


FIG. 2.

As one cannot take into consideration all the conditions which govern and modify the cycle of any motor, the usual practice is to calculate the power on the assumption that all theoretical conditions are complied with, and then modify the result by a certain coefficient of efficiency which practice has established for the particular type of motor under consideration.

We will therefore examine more closely the isothermal and adiabatic transformations in order to ascertain the quantity of external work which these transformations can furnish for a given expenditure of heat and a given fall in temperature.

External work done by an isothermal transformation. Heat absorbed.—Let U represent the energy (manifested to us as temperature) contained in a kilo of gas, Q the heat

stored up in this gas, and W the external work, then we shall have the fundamental equation

$$dQ = dU + dW.$$

This simply means that any gain or loss of heat entails a corresponding variation in the caloric energy of the gas, and, in some cases, either positive or negative external work, the sum of these two variations being equal to dQ.

But the energy U of a gas depends upon its temperature alone, just as the potential energy of a body depends upon its height above ground. Therefore we can say that

$$U = f(T),$$

which equation has been experimentally proved correct by Joule, and bears his name.

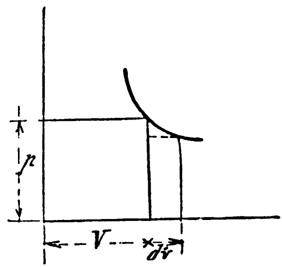


Fig. 3.

It follows, therefore, that all the heat supplied during an isothermal transformation does not increase the energy U of a gas, as by our definition we work at a constant temperature. The caloric energy will alone do the necessary external work.

For an infinitely small change of volume (Fig. 3) the external work done will be represented by

$$dW = pdv,$$

and the total work of an isothermal expansion from p_0 to p_1 will be the integral of the above differential. v_0 v_1

We have, therefore,

$$W = \int_{v_0}^{v_1} pdv\,;$$

and as

$$p = \frac{p_0 v_0}{v},$$

the integral becomes

$$W = \int_{v_0}^{v_1} \frac{p_0 v_0}{v} dv = p_0 v_0 \int_{v_0}^{v_1} \frac{dv}{v};$$

and we have therefore

$$W = p_0 v_0 \log_e \frac{v_1}{v_0}.$$

Let Q be the heat that has been required to keep the temperature constant, and we have

(4) $$Q = A.p_0 v_0 \log_e \frac{v_1}{v_0},$$

in which $A = \frac{1}{E} = \frac{1}{425}$. E is what is termed the *mechanical equivalent of heat*; that is, the number of kilogrammetres which correspond to a calorie. This equation, therefore, gives the heat required and the work done by an isothermal expansion.

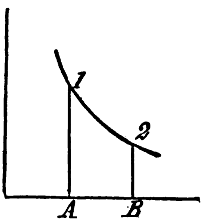


Fig. 4.

Work done during an adiabatic expansion.—According to the definition, this operation must take place without gain or loss of heat, so that

(4) $$dQ = O.$$

If from a point 1 in the *adiabatic* curve (Fig. 4) we expand the gas to 2, the external work represented by the area A 1 2 B will be equivalent to the decrease of the internal energy of the gas.

Let us again take equation (4) and substitute for dQ its equivalent:

$$dQ = dU + dW = O;$$

or

$$dU + Apdv = O,$$

(5) $$\left(\frac{dU}{dp}\right) dp + \left(\frac{dU}{dv} + Ap\right) dv = O.$$

Then, assuming the volume of the gas to be constant, a change of pressure will entail a corresponding change of internal heat equal to

$$C_v dt = \frac{dU}{dp}\,dp,$$

C_v being the *specific heat of a gas with constant volume.*

Similarly, assuming the pressure to be constant, we shall have

$$\left(\frac{dU}{dv} + Ap\right)dv = C_p dt,$$

C_p being the *specific heat of a gas at constant pressure.*

The specific heats C_p and C_v can almost be considered to be independent of the temperature. The ratio between C_p and C_v is generally expressed by γ.

By substituting in equation (5) the above values for

$$\frac{dU}{dp}\,dp \quad \text{and} \quad \left(\frac{dU}{dv} + Ap\right)dv,$$

we obtain

(6) $$C_v \frac{dt}{dp}\,dp + C_p \frac{dt}{dv}\,dv = O.$$

But we know that the energy of a gas, represented by the product of its pressure into its volume, is a function of its temperature alone ; we can therefore say

$$pv = RT,$$

R being a constant for all gases.

We deduce hence that

$$\frac{dt}{dp} = \frac{v}{R} \quad \text{and} \quad \frac{dt}{dv} = \frac{p}{R}.$$

By substitution equation (6) becomes

(7) $$C_v \frac{v}{R}\,dp + C_p \frac{p}{R}\,dv = O.$$

Dividing both sides of the equation by $C_v \times \frac{pv}{R}$ we get

$$\frac{dp}{p} + \gamma \frac{dv}{v} = O.$$

the integral of this equation being :

$$\log_e \frac{p_2}{p_1} + \gamma \log_e \frac{v_2}{v_1} = 0 ;$$

or again :

(8) $$p_2 v_2^\gamma = p_1 v_1^\gamma = \text{constant.}$$

This is the general equation of an *adiabatic* expansion ; it enables one to calculate the work done during this expansion, as follows :

$$W = \int_1^2 p dv ;$$

but

$$p_2 = p_1 v_1^\gamma \frac{1}{v_2},$$

whence

$$W = p_1 v_1^\gamma \int_1^2 v^{-\gamma} dv.$$

By integration we find

(9) $$W = \frac{p_1 v_1^\gamma}{1-\gamma} \left(v_2^{1-\gamma} - v_1^{1-\gamma} \right).$$

which is the work done theoretically by an adiabatic expansion.

If we represent the internal energy of the gas at points 1 and 2 by U_1 and U_2, the difference between U_1 and U_2 will, from what we have shown, be equal to the external work ; we shall therefore also have

(10) $$U_1 - U_2 = A.W = A \frac{p_1 v_1^\gamma}{1-\gamma} \left(v_2^{1-\gamma} - v_1^{1-\gamma} \right).$$

Carnot's Cycle.—Amongst the various cycles or transformations through which a gas may pass there is a very important one which it is always sought to obtain in practice.

The cycle in question is formed by two isothermal lines and two adiabatic lines (Fig. 5).

The line AB represents an isothermal expansion at a temperature t_2.

The cylinder containing the gas is isolated at a point B, so that the working substance may neither receive nor give out heat, and from B to a point C, which corresponds to a temperature t_1, the expansion is effected adiabatically.

From C the gas is compressed, but is maintained, however, at a constant temperature t_1. This is an isothermal compression which must stop at D, so that the cycle may be completed by an adiabatic operation from D to A.

From D to A, then, we operate by adiabatic compression.

Such are the four stages which form the Carnot cycle.

The values that we have found for adiabatic and isothermal expansions enable us to thoroughly analyse what takes place during a Carnot cycle and to establish certain theorems upon which the science of modern thermo-dynamics is based. We do not intend to pursue our examination of this cycle any further, as it would lead us too far. A brief outline suffices, because, the cycles being all different in practice, not much advantage would be gained for the investigation of those motors which we propose to examine.

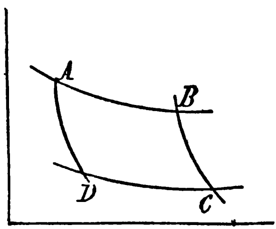


FIG. 5.

The principle which we deduce from the above is known as *Carnot's Principle*, and may be stated as follows : *The ratio of the amount of heat converted into work to the amount of heat taken from the source of heat is a constant for all substances working according to Carnot cycles between the same limits of temperature.*

Let Q_2 be the amount of heat taken on the isothermal t_2 and Q_1 the amount given on the isothermal t_1, we can always state that

$$(11) \qquad \frac{Q_2 - Q_1}{Q_2} = \frac{Q'_2 - Q'_1}{Q'_2} = \text{constant.}$$

But if, on the other hand, we make

$$\frac{dQ}{T} = d\mu$$

we find that

$$Q = \int T d\mu,$$

whence

$$Q = T\,(\mu_2 - \mu_0)\,;$$

so that we obtain

$$Q_2 = T_2\,(\mu_2 - \mu_0)$$

and

$$Q_1 = T_1\,(\mu_2 - \mu_1)\,;$$

and equation (11) becomes

(13) $$\frac{Q_2 - Q_1}{Q_2} = \frac{T_2 - T_1}{T_2}.$$

The ratio $\frac{Q_2 - Q_1}{Q_2}$ is the *efficiency* of the cycle ; that is, the ratio which the heat converted into work bears to the heat taken from the source. One sees at once that the efficiency varies inversely with T_1 and directly with T_2.[1]

Cycle of a Steam-Engine.—Every one knows how a steam-engine works. The water in the boiler is first converted into steam at the required pressure. The steam then passes into a cylinder, where it works at maximum pressure during a portion of the stroke of the piston. At a certain point the admission of steam is cut off, and the steam in the cylinder then expands till its pressure falls to about $1\frac{1}{4}$ atmospheres, when it is allowed to escape into the atmosphere. If a condenser is used the pressure at exhaust may fall to $\frac{1}{4}$ atmosphere, and even below that. The exhaust takes place during the back stroke of the piston, and the pressure still acting on the piston is called *back pressure.*

[1] For further details see *Théorie mécanique de la Chaleur*, by Charles Briot.

The exhaust ceases at a point D near the end of the stroke, and from this point the steam is compressed till it nears original pressure.

The volume occupied at A (Fig. 6) by the steam is known as *clearance.* One sees at once that the cycle of a modern steam-engine is far from resembling Carnot's ideal cycle.

The first isothermal operation from A to B is carried out at constant pressure, so that the external work done during that time is expressed by

$$P_0 \int_{v_0}^{v_1} dv = P_0(V_1 - V_0),$$

V_0 being the clearance.

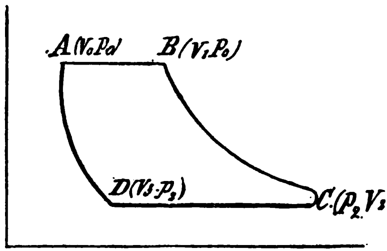


FIG. 6.

Whilst the steam is expanding from B to C heat escapes through the sides of the cylinder, so that the operation is not an adiabatic one.

Moreover, some of the water which has condensed on the cold cylinder barrel during admission forms into steam during the period of expansion, which complicates matters.

All these phenomena modify the expansion to such an extent that, instead of calculating the work done as we did in the case of an adiabatic expansion, it is found more convenient in practice to consider the expansion as an isothermal one, so that we may use equation (3) (see page 8) :

$$W = P_0 V_1 \log_e \frac{V_2}{V_1}.$$

The exhaust takes place from C to D, and the negative work corresponding to this stage of the cycle is expressed by

$$P_2 \int_{v_2}^{v_3} dv = - P_2(V_2 - V_3).$$

The negative work required for the compression is found by the formula given above for expansion.

In the chapter on *The Theory of Motors* we shall enter more fully into the working of steam motors, and show how to calculate their principal dimensions for any given power required.

For the present we will merely state that their efficiency is far below Carnot's ideal cycle. Speaking on this matter, Mr. Dwelshauvers-Déry, professor at the University of Liège, says: —

'The breaks in cycles which are inevitable in our present engines considerably reduce the proportion of heat that can be utilised. This reduction is as much as 13 per cent. in the best engine imaginable, more than a third of the amount of heat which theoretically should be at our disposal.

'The maximum practical amount of heat available for work is about 20 per cent. of the heat expended, and no possible improvements can very much affect this limit, which corresponds to a consumption of 4·849 kilogrammes [1] of water per horse-power per hour at the rate of 655 calories per kilogramme, which is the total heat of six atmospheres at absolute tension.

'We can never hope to lower consumption of steam to five kilogrammes [2] per horse per hour, inasmuch as the action of the cylinder walls affects the operations we have analysed,[3] and losses take place which can never be entirely avoided. This action of the walls is such that even in some engines provided with good condensers the portion of heat represented by the work indicated forms but a small proportion of the maximum 20 per cent.'

We may add that, in addition to these losses of heat, that is, of work, in the cylinder itself, there are losses inherent to the boiler which always amount to at least 40 per cent.

In our best engines the amount of heat converted into

[1] 10·77 lbs. [2] 11·00 lbs.

[3] Dwelshauvers-Déry, *Etude calorimétrique de la machine à vapeur.*

work in the motor is 8 per cent. of the total heat, and, as the boiler efficiency is at best 60 per cent., our engines only use

$$0{\cdot}08 \times 0{\cdot}6 = 0{\cdot}048,$$

or 4·8 per cent. of the heat evolved by the coal combustion. These figures correspond to an expenditure of about 8 to 9 kgs.[1] of steam per horse-power per hour at a pressure of 7 atmospheres, which, with a good boiler, means a combustion of 900 grammes[2] of fuel.

We shall conclude this chapter with a few words on the resistance to traction of cars along roads or on rails.

PULL OF CAR ON RAIL AND ROAD.

In both these cases the resistance to traction depends to some extent on the diameter of the axle journals, although the general rule is to adopt a coefficient of traction proportional to the weight of the car.

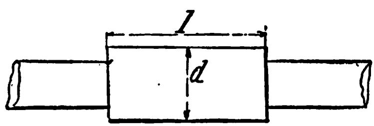


FIG. 7.

In calculating the dimensions of a journal two essential conditions must be considered :

1st. The pressure on the journal must not cause excessive heating. A certain pressure per square centimetre, found experimentally, is allowed. Let l (Fig. 7) be the length and d the diameter of a journal, then

$$(A) \qquad ld = \frac{P}{p},$$

where P is the total pressure on the journal and p a coefficient proportional to the pressure per square centimetre, which is generally taken at 20 kilos. per square centimetre.

2nd. The sectional area of the journal must be sufficient to resist fracture. It must therefore always be equal to

$$(B) \qquad \frac{\pi d^2}{32} = \frac{P\frac{l}{2}}{R'}$$

[1] 19·8 lbs. [2] 1·98 lbs.

where R′ is the load per square centimetre which the metal can safely carry. For auto-cars the rule is to make $R' = 300$ kgs. per square centimetre when iron axles are employed.

Formulæ (A) and (B) enable us to find the length l and diameter d of any journal.

It is self-evident that the larger d is the higher will be the coefficient of resistance to traction, as the leverage of the axle friction will increase, all other things being equal, with the distance of the rubbing surface from the axis of rotation This coefficient will also vary inversely with the diameter of the driving wheels, which for this reason should be made as large as possible.

On rail the coefficient of resistance is about $\frac{1}{100}$ of the load carried when flanged tyres are used, and about $\frac{1}{147}$ with flat tyres. The tractive force can be calculated from these data without considering the size of the wheels or journals.

Let P represent the weight of a car, f the coefficient of resistance, and i the incline per metre, then the total resistance will be

$$E = P(f \pm i), \tag{14}$$

the sign $\pm$ being the incline. The work for a distance l run on a uniform road will therefore be

$$W = Pl(f \pm i)\ ; \tag{15}$$

and the power required, v being the speed in metres per second, will be

$$W' = Pv\,(f \pm i) \text{ kilogrammetres,}$$

or

$$W' = \frac{Pv\,(f \pm i)}{75} \text{ horse-power.} \tag{16}$$

Mr. Reckenzaun has remarked that the resistance to traction is doubled on curves of 15 metres radius (49 ft.), and is trebled on 10-metre (33-ft.) curves.

It is frequently the quadruple at starting.

The adhesion of a car on rails varies from $\frac{1}{5}$th to $\frac{1}{10}$th of the weight on the driving wheels. Therefore if the force exerted at starting is too great the wheels will skid.

Let p be the load carried on the driving axle, then the following must always hold :

(17) $$p.f' = P(f' + i),$$

where f' is the coefficient of adhesion, which may vary from 0·25 to 0·10, i being the steepest gradient.

This formula enables the minimum load on the driving wheels to be determined beforehand for a single self-propelled car, or for a car or tractor hauling another one. In the latter case P represents the weight of the hauling car plus that of the hauled car with its load.

The case is much more difficult for a car running on an ordinary road ; the general practice is to adopt a coefficient of resistance of 0·06.

This figure may vary very much according to the state of the road and the kind of tyre used. There is no doubt, however, that 30 per cent. or 40 per cent. is saved in resistance to traction by using pneumatic tyres. The coefficient then becomes 0·042 to 0·036, but it can be reduced still further by using ball bearings, and may even become less on road than on rail.

In our opinion, pleasure auto-cars should be built as light as possible, so as to enable them to have all the recent improvements which have been applied to bicycles.

In estimating the tractive force required we have not hitherto taken into consideration the resistance of the air. This resistance does not affect the question much for heavy cars going at slow speed, but for light cars travelling fast it becomes important.

The following table gives the wind resistance, which increases, roughly, with the square of the velocity.

Take, for instance, a car whose front elevation has an area

of 3 square metres going at a speed of 20 kilometres an hour. If there is no wind, the resistance to passage through the air will be 3·2 kgs. $\times$ 3^{m2} = 9·6 kgs., as a speed of 20 kilometres an hour, or 5·5 metres per second, is equivalent, from the table below, to a pressure of 3·2 kgs. per square metre.

Nature of wind		Velocity in metres per second	Velocity in feet per second	Pressure in kilogrammes per square metre	Pressure in lbs. per square foot
Wind slightly perceptible		1	3·28	0·14	0·02
Light breeze		2	6·56	0·54	0·11
Breeze		4	13·12	2·17	0·44
Fresh wind	filling sails	6	19·68	4·87	0·98
	the best for windmills	7	22·96	6·64	1·34
	strong breeze	8	26·24	8·67	1·75
	for sailing ships	9	29·52	10·97	2·25
Very fresh wind	very strong breeze	10	32·79	13·54	2·76
	reefing topsails	12	39·36	19·50	3·90
Very strong wind		15	49·20	30·47	6·23
Boisterous wind		20	65·61	54·16	11·08
Tempest		24	78·72	78	15·97
Violent tempest		30	98·40	122	24·98
Hurricane		36	119·11	177	36·25
——		40	131·22	186	38·04
Cyclone		45	147·63	277	56·73

The engine will therefore have to exert an extra power of 9 to 10 kilogrammetres in order to keep up the speed of the car. The resistance to traction is increased by 9 or 10 kilogrammetres. If the car were travelling against a very strong breeze, equivalent to a speed of 10 metres per second, the resistance would be increased by 31 kgs. $\times$ 3 = 93 kgs., or more than one horse-power above the required calculated power without counting the wind resistance.

It is easy to see the advantage of building cars with a small cross section. In some cars it would even be advisable to shape the body of the car like the prow of a ship. This question of wind-resistance increases in importance as the speeds attained are higher.

We have laid some stress on this point because we feel sure that light, and not bulky, cars will be in great request for self-propelled traffic on common roads. The same pleasure will be experienced in using these cars as is obtained at present by bicyclists. To possess a steed which neither tires one nor tires itself, to roam at will on the most picturesque roads and visit the most charming sites, and to stop where one chooses and then start again in search of fresh fields and pastures new, are advantages not to be lightly despised.

Auto-cars, in our opinion, will be chiefly used for touring and pleasure trips. Tractors for hauling heavy loads do not seem to meet a want, and for traffic of this kind between villages we think a light railway on the Decauville system will be found far preferable.

We will go more fully into the theory of motors in the following chapters, explaining in greater detail the fundamental points which we have touched upon in this chapter.

CHAPTER II

GENERAL AND HISTORICAL

It is difficult to give the exact date when the self-propelled vehicle was first invented. There are documents dating as far back as the Egyptians showing a car propelled by the action of steam escaping into the air. Who knows if, better still, they did not use some kind of steam-engine for carrying out their gigantic engineering works! However that may be, it is only since Denis Papin that we have known what power steam can produce under pressure, and the first self-propelled or auto-car of which we have any reliable information dates back to the year 1771. The inventor, Cugnot, was an artillery officer, who may be said to have foreseen the extensive application which this kind of locomotion would have. This invention was merely a primitive car running indifferently through the bogs and slushes of Paris at a rate of about 2½ miles an hour. This venerable ancestor has been carefully preserved at the Conservatoire National des Arts et Métiers in Paris.

About the same time Worcester invented an engine for raising water. Newcomen did better, for he was the first to build a working engine worthy of the name, but the first properly so-called steam-engine is due to Watt. He was, without doubt, one of the greatest geniuses of modern times, for he built a complete steam-engine, and whereas his predecessors had only made incomplete models, he left us a real masterpiece, perfect from every point of view, which we have only been able to improve by modifying the details. Watt

invented double action, the condenser, the air pump, the regulator, and expansion. He caused the consumption of fuel to fall from 22 lbs. to 8·8 lbs. per horse-power per hour. In 1829 Robert Stephenson, the pioneer of the locomotive engine, built the first practical locomotive engine, the 'Rocket.'

Fig. 8 shows this engine, which ran regularly between Manchester and Liverpool. Let us add, to be just, that in 1808 Trevithick built two separate types of engines, the first for road locomotion and the second for running on flat rails. These two were built before the Rocket, and worked fairly well, but did not attain speeds of 25 miles an hour, like the latter. From that time forward the locomotive on rails made such great progress that forty years later the whole of Europe was provided with railways.

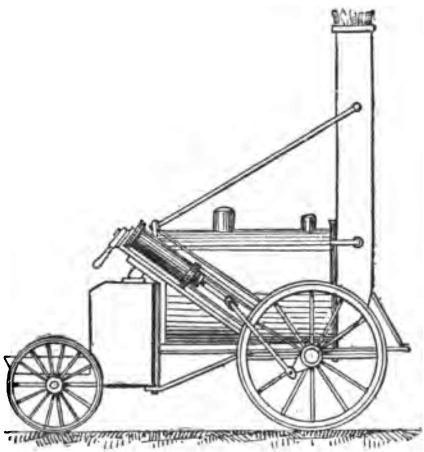


FIG. 8.—'The Rocket.'

Apart from a few trials which failed, the road locomotive was completely abandoned, at least as far as passenger traffic is concerned. The motors, and, above all, the steam generators, were still too heavy, too cumbersome, and too dangerous to enable the grand problem of self-propelled traffic along public roads to be solved in a practical manner.

Bicycling has again brought the subject to the front, and numerous inventors have sought to substitute an engine for the human motor on the bicycle and tricycle.

Messrs. de Dion & Bouton were the first, we think, to

attempt the solution of this problem by means of the steam motor. Their first trials date back to 1882, but from the start they were stopped by a great difficulty—*the generator.*

In the first place, Messrs. de Dion & Bouton had to invent a suitable boiler, and it was only after two years of research that their efforts were crowned with success. The generator which is called after them was adopted by the French Navy for their torpedo boats on account of its small volume and its high steaming power.

It was first applied to a quadricycle seating two, and then to a *Tandem* tricycle, in which the second seat was utilised for carrying a motor and a generator, weighing together about 110 lbs. The engine of one horse-power enabled a speed of 18½ miles an hour to be attained, which even now may be considered a very satisfactory result. In 1885 Messrs. de Dion & Bouton built a tricycle which covered 0·62 mile in one minute. This is, therefore, the first light, rapid, and easily controlled auto-car which has run on our roads.

Three years later Mr. Serpollet applied his generator *without water* to a tricycle, and obtained exceedingly satisfactory results. We will describe this apparatus further on; for the moment we will merely state that it is the only steam system which is allowed to run within Paris. Already several tramway lines have adopted the Serpollet generator, which enables them to obtain a very appreciable saving on animal traction.

But even as far back as 1860 Lenoir had designed a gas motor which worked regularly, and had sought inspiration from the ideas of Beau de Rochas, the real discoverer of this new type of motor, which appears to have such a brilliant future before it for self-propelled road traffic. Since then this system has been improved upon, and the race of auto-cars from Paris to Bordeaux and back in 1895 placed it in the first rank of the various systems adaptable to this kind of traffic.

The petroleum auto-car is only one or two years old. In

1894 it was not fairly represented in the *Petit Journal* competition, organised by Mr. Pierre Giffard, in which steam cars certainly obtained the greatest success. We owe the first practical petroleum motor for road locomotion to the German Daimler, and even to-day his motor still occupies the first rank. Messrs. Panhard & Levassor and the firm Peugeot, both car-builders, were the first to foresee the prospects of *petroleum*, and they adopted and still continue to use the Daimler motor for working their cars. The ancient history of petroleum cars is therefore to-day's, and the rapid progress which has been made within a year enables us to build the greatest hopes on this rival of steam.

The race from Paris to Bordeaux last year has proved this; petroleum gained a brilliant victory, the first eight arrivals in this great race being cars propelled by petroleum motors. Let us remind our readers that M. Yves Guédon, secretary to the Organising Committee of the race, resigned his duties after the race in order to prepare jointly with M. Clément, the well-known French manufacturer, for the race Paris to Marseilles and back, which took place in October last. The auto-cars which will enter for the race on behalf of M. Clément, under M. Guédon's direction, may become dangerous rivals to those propelled by the Daimler motor.

Besides steam cars for tramway purposes, we have also electric and compressed air cars.

The use of compressed air is quite recent; in fact, leaving aside the experiments carried out in 1840 by two French engineers, Messrs. Andraud and Tessier du Motay, which had no practical results, we must go back to 1872 for the first practical work carried out by Mr. Mékarski. We know, in fact, that much of the work done up till now in applying compressed air to tramway traction is due to this engineer.

On November 4, 1872, Mr. Mékarski tock out a patent, No. 97,072, for a compressed air motor *with regulated pressure.* On June 23, 1873, he took out an additional patent for

heating air by mixing it with steam, and this completed his system as it is worked to-day.

In 1873 Mr. Mékarski built the first experimental engine, which ran in 1874 on the private railway of Maltournée from the plaster quarries of Neuilly-Plaisance.

At the same time a compressed air locomotive for tunnelling the St. Gothard was built at Creuzot, and was fitted with Mr. Mékarski's pressure regulator.

At the end of 1875 and during 1876 numerous experiments were made with the first auto-car for tramways on the Courbevoie-l'Etoile tramway line. These experiments, witnessed by the most eminent scientists of France, were exceedingly successful, and in consequence Mr. Mékarski obtained a concession for tramways at Nantes. These tramway lines were opened to traffic on February 13, 1879, and have since always worked without a hitch; they are very economical (the cost of working per car mile during the last ten years has only been 4·25*d.*).

The first line of compressed air tramways subsequently built was that of the Nogentais tramways, in August, 1887. The depôt is placed where the experimental plant for the first trials had been set up.

Meanwhile Mr. Mékarski went on improving his compressed air apparatus with the object of obtaining a much higher pressure, and also of storing a greater amount of air in the same volume.

He succeeded in storing air at a pressure of 427 lbs. per square inch in the tanks on the Etoile tramway.

As this air was only employed at a pressure of 142 lbs. in the cylinders of the motors, the work done in compressing air from 142 lbs. to 427 lbs. was lost, but unfortunately the only method of storing a large amount of energy in a small volume is to have an exceedingly high pressure. Mr. Mékarski saw this, and in all his new plant the air is compressed at a pressure of 1,138 lbs. per square inch.

On the line from Vincennes to St. Augustin, in Paris, there are 24 auto-cars, of which 20 are used daily, one being in reserve and three in the repairing sheds. From this it will be seen that in buying auto-cars a certain saving in prime cost is realised, which compensates to some extent for the cost of compressors, boilers, and charging apparatus.

During the last ten years electricity has, even more than compressed air, become one of the most useful means for tramway traction. Electric traction was first studied in Europe by Messrs. Siemens and Halske, and it was taken up in the United States, where it has been greatly extended. In less than three years 130 cities in the United States have adopted electric traction, which is equivalent to a total mileage of 1,860 miles. It has been substituted for animal traction almost all over the United States, but in Europe this method of traction has gained less partisans. It is necessary to have a copper wire $\frac{3}{8}$ inch in diameter, above the line, supported by poles at certain distances apart. This was considered unsightly, and is the only reason given by our town authorities for the non-adoption in our large cities of so adaptable, so clean, and so rapid a method as electric traction.

True, overhead wires can be dispensed with by using *accumulators*, but the general efficiency is much impaired by the great increase in dead weight due to the accumulators. This system, however, is much employed in Europe, and has given good results. Accumulators have also been used for road traction, but up to the present the results leave much to be desired. We may mention Mr. Jeantaud as one who has done much good work in this direction, and who obtained a comparative success in the Paris-Bordeaux race.

In our opinion, road traction by electricity will only be possible when we have found a good generator of electric energy, and accumulators cannot be considered as such. What would be thought if Mr. Mékarski were to recommend his system for attaining the same end? It would be thought ridiculous,

and yet no objection is found to the accumulation of electricity, although both systems are exactly similar; for, whether we store electricity or compressed air, we are always storing the power originally supplied by a steam-engine. Possibly air accumulators are even less liable to deteriorate than electric accumulators, and their capacity is certainly at least as great per unit of weight.

Besides electricity and compressed air as tractive forces, we have had *liquid carbonic acid*, which was employed a few years ago for the first time. It was, however, not a commercial success, and has since been given up, so we will not deal with it in the present work, because we have already so much to say on really practical applications of steam, electricity, compressed air, and petroleum that we have no space to speak of systems that have been abandoned, although, of course, it is quite possible that some of them may hereafter be taken up again.

CHAPTER III

THEORY OF VARIOUS TYPES OF MOTORS

Steam Motors

We will deal with the steam motor very briefly, and chiefly from the point of view of its application to road locomotion. With the exception of tractors, the power required rarely exceeds four or five horse-power, so that neither compound expansion nor condensers are necessary. Our steam motor will therefore be of the very simplest kind. Let us begin by describing the method of calculating the dimensions of a motor for any given power required.

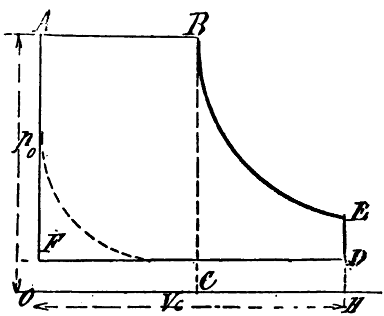


FIG. 9.

CALCULATION OF PARTS OF SINGLE-CYLINDER EXPANSION ENGINE

The work done (Fig. 9) by a double stroke of the piston (to and fro) is given by the area *A B E D F*. Suppose the engine to be *single-acting*, *i.e.* with steam admitted on one side of the piston only. A *double-acting* engine does twice as much work. Let us assume, also, that there is no compression as shown on figure.

First stage. Full admission of steam.

$W_0 =$ work done $= A\ B\ C\ O = P_0 V_C$.

$P_0 =$ total pressure on piston in kilogrammes.

$V_0 =$ volume of steam after admission.

If we call p_0 the pressure of steam on admission in kilogrammes per square centimetre, S^2 the area of piston, and l_0 the stroke; when the piston reaches a point B we shall have

$$(a) \qquad W_0 = p_0 \,.\, S^2 \,.\, l_0.$$

Second stage. Expansion.

Taking equation (3), we find

$$W_1 = \text{work of expansion} = BEHC =$$
$$= P_0 V_0 \,.\, \log_e \frac{V_c}{V_0},$$

V_c being the volume swept by the piston.

We shall therefore have

$$(b) \qquad W_1 = p_0 \frac{l_c}{n} S^2 \log_e n,$$

$l_c =$ total stroke of piston.

$n =$ *degree of expansion* $=$ ratio of total volume to volume swept up to point of cut-off.

Third stage. Exhaust.

$$W_2 = F\,D\,H\,O = P_1 V_c$$
$$(c) \qquad W_2 = p_1 \,.\, l_c \,.\, S^2\,;$$

p_1 being the back pressure in kilogrammes per square centimetre acting on the piston during exhaust.

The total work the engine can do for one stroke will therefore be

$$W_t = W_0 + W_1 - W_2 = p_0 S^2 \left[l_0 + \left(\frac{l_c}{n}\right) \log_e n - \frac{p_1}{p_0} l_c \right]$$

$$(17) \qquad W_t = p_0 l_0 S^2 \left[\log_e .\, n\,. + 1 - \frac{p_1}{p_0} n \right].$$

This is the formula expressing the theoretical work done; but, having regard to the fact that in practice the cycle is far from resembling the ideal cycle, W_t is multiplied by an experimental coefficient K_a in order to obtain the work measured on the indicator diagram.

Therefore

$$W_i = K_a W_t.$$

The power available on the pulley will be equal to the work indicated, less loss due to friction. For this another coefficient, K_0, is taken as a multiplier of W_i, so that

$$W_u = K_0 K_a W_t = K_u W_t$$

where $K_u = K_0 K_a$.

Finally, therefore,

$$(18) \qquad W_u = K_u \,.\, p_0 l_0 S^2 \left[1 + \log_e n - \frac{p_1 n}{p_0}\right].$$

The degree of expansion varies generally from 5 to 6 and the back pressure p_1 from a half to three-quarters of an atmosphere for *condensing* engines.

p_0 will rarely exceed 6 or 7 atmospheres.

K_u varies with the engine horse-power, and the subjoined table gives the values of K_u which are generally taken.

Horse-power	Without cut-off		With cut-off	
	Non-condensing engines Ku	Condensing engines Ku	Non-condensing engines Ku	Condensing engines Ku
4·8	0·6	0·55	0·45	0·4
8·15	0·65	0·6	0·5	0·45
15·15	0·68	0·65	0·6	0·55
25·4	0·72	0·68	0·65	0·6
40·6	0·75	0·7	0·7	0·65
60·8	0·8	0·75	0·75	0·7
80·12	0·82	0·78	0·8	0·75
above	0·85	0·8	0·82	0·77

Equation (18) enables one, therefore, to find the dimensions of a steam motor which is required to do W_u kilogrammetres of work per stroke of piston. Let us take an example, and

calculate the stroke and diameter of the cylinder of a single-acting engine which is to give 10 horse-power at 300 revolutions per minute.

We shall have

$$W_u = \frac{10 \times 75 \text{ kilogrammetres} \times 60}{300} = 150 \text{ kilogrammetres.}$$

So that

$$150 = K_u \,.\, p_0 \frac{l_c}{n} S^2 \left[1 + \log_e n - \frac{p_1 n}{p_0} \right].$$

The pressure of admission being 6 atmospheres, and the degree of expansion 5, we have, for a non-condensing engine,

$$\begin{aligned} p_0 &= 60000 \text{ kgs. per square metre.} \\ n &= 5 \\ p_1 &= 15000 \text{ kgs. per square metre.} \\ K_u &= 0{\cdot}5. \\ \log_e n &= 3{\cdot}91. \end{aligned}$$

By substitution we shall have

$$150 = 0{\cdot}5 \,.\, \frac{60000}{5} \,.\, l_c S^2 \left(1 + 3{\cdot}91 - \frac{1{\cdot}5 \times 5}{6}\right)$$

$$150 = 6000 \times 3{\cdot}66 \times l_c S^2 = 21960 \times l_c S^2 ;$$

whence

$$l_c S^2 = \frac{150}{21960} = O^{m3}\,0071 = l_c \,.\, \pi r^2.$$

The ratio $\frac{l_c}{r}$ is generally fixed arbitrarily, and should be less for high-speed than for low-speed engines.

We may take in our case $\frac{l_c}{r} = 4$, which makes

$$3{\cdot}14 \,.\, 4 r^3 = 0{\cdot}0071 ;$$

whence

$$r = \sqrt[3]{\frac{0{\cdot}0071}{12{\cdot}56}} = \sqrt[3]{0{\cdot}00056},$$

so that

$$r = 0{\cdot}0825_{\text{m}},$$

or

$$D = \text{diameter of piston} = 16{\cdot}5_{\text{cm}}.$$

By substituting the value of r, the equation

$$l_c = 4r$$

enables the stroke of the piston to be calculated :

$$l_c = 4 \times 8{\cdot}25_{\text{cm}} = 33 \text{ centimetres.}$$

The cylinder must be made slightly longer than l_c to allow for *clearance*. When there is compression just before the end

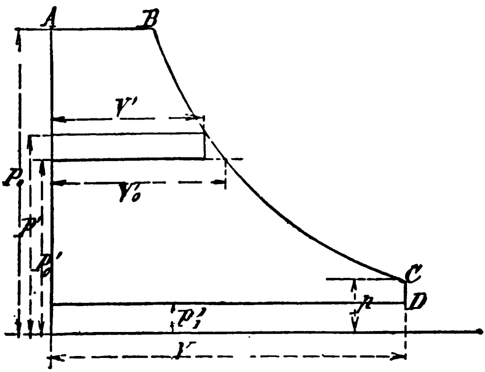


FIG. 10.

of stroke the clearance must be such that the pressure of compressed steam contained therein shall equal the pressure of steam admitted at beginning of stroke.

The same calculations would have held good for a *double-acting* engine, but in that case the 150 kilogrammetres required per stroke of piston would have been halved.

Compound engines.—Engines with two cylinders are used for high pressures. The steam, having gone through its cycle in the first cylinder, passes into a second cylinder, and from thence into a condenser or into the atmosphere, as the case

may be. The two cylinders are generally cast together, and work simultaneously. Fig. 10 shows the cycle followed by the steam.

Let

V = volume of the large cylinder, shown by the abscissa ED;
V' = volume of the small cylinder;
r_0 = ratio $\frac{V}{V'}$;

$$m = \frac{V'_0}{V'};$$

V_0 = volume at which steam is admitted to the small cylinder;
n = total expansion $\frac{V}{V_0}$;
n_0 = partial expansion $\frac{V'_0}{V_0}$ in small cylinder;
V'_0 = volume at which steam is admitted into large cylinder after leaving the small cylinder;
n_1 = partial expansion $\frac{V_0}{V}$ in large cylinder;
p_0 = pressure of steam admission in large cylinder;
p'_0 = pressure of steam admission in small cylinder;
p'_1 = pressure of exhaust in large cylinder.

Calculation of volume of large cylinder.—This is effected in the same manner as for a single-cylinder engine working with a pressure of admission p_0 and a total expansion n. The coefficient K_0 of *mechanical efficiency* is, however, slightly less, so that, as K_u varies also, we must call its new value K'_u, which has been found experimentally to equal

$$K'_u = 0{\cdot}9\ K_u.$$

Calculation of volume of small cylinder.—Both cylinders in *compound* engines are generally designed to work together, which enables the transmission gear to have the same dimensions.

We can therefore lay down the following equation :

$$(19)\qquad \begin{cases} p_0\, V_0 \left(1 + \log_e n_0 - \dfrac{n_0 p'_0}{p_0}\right) = \\ = p'_0 V'_0 \left(1 + \log_e n_1 - \dfrac{n_1 p'_1}{p'_0}\right). \end{cases}$$

From previous hypotheses, BC being an isothermal curve, we shall have

$$(a)\qquad p_0 V_0 = p'_0\, V'_0\,;$$

or

$$p'_0 = \frac{p_0 V_0}{V'_0}.$$

And as

$$V_0 = \frac{V'_0}{n_0 m},$$

we shall also have

$$(b)\qquad p'_0 = \frac{p_0}{n_0 m}.$$

Similarly

$$n_1 = \frac{V}{V'_0}\,;$$

and as

$$V'_0 = V_0 n_0 m$$

and

$$V_0 = \frac{V}{n},$$

we find that

$$(c)\qquad n_1 = \frac{n}{n_0 m}.$$

Taking equations (a), (b), and (c) into consideration, equation (19) becomes

$$(20)\qquad 1 + \log_e n_0 - \frac{1}{m} = 1 + \log_e \frac{n}{n_0 m} - n\,\frac{p'_1}{p_0}\,;$$

n, p'_1 and p_0 being known, the value of n_0 can be found, and then V' and V'_0 can be calculated from equations

$$V' = n_0 V_0$$

and

$$V'_0 = mV' = mn_0 V_0 = \frac{m_0 n_0 V}{n}.$$

The volume of the small cylinder is therefore found, and the problem becomes similar to the one dealt with in a single-cylinder engine.

Besides *single-cylinder* and *compound* engines we have triple and even quadruple expansion engines. To find the cylinder dimensions of these latter the same method must be followed as for *compound* engines, care being taken, however, to allow for decrease of mechanical efficiency.

Only single or double expansion steam motors are used for traction purposes. If complication is not objected to, though it should be avoided as far as possible for road motors, practice tells us that it is better to employ single-cylinder engines for pressures up to 4 atmospheres, compound engines from 4 to 7 atmospheres, and triple or quadruple expansion engines for higher pressures.

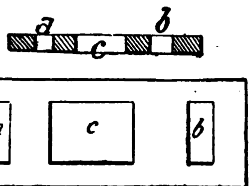
As we have already said, the general tendency is to simplify road motors as far as possible, more particularly as they are often driven by inexperienced people. For this reason we find that single-cylinder engines are almost always used, the compound principle being only adapted to large motors of 50 or 100 horse-power.

The condenser, which is largely used in marine and stationary engines, is never employed for steam traction, on account of the quantity of water it requires, and for this reason road motors can never have a very high efficiency. For 4 or 5 horse-power engines the consumption of water is generally 20 kgs. (44 lbs.) and of fuel 2 kgs. (4·4 lbs.) per horse-power per hour, and the boiler must be designed in accordance with this estimate.

Valve Gear.—Once the size of the cylinder has been settled for a given power and given degree of expansion, the valve gear must be arranged to obtain the cycle which has been decided upon. For many years valves and cocks were used which were opened and shut at the required moment by suitable mechanical devices. The latter, however, were comparatively complicated, so that now it has been found preferable when dealing with low power to use a simple *slide valve*, which obtains all the required stages of the cycle during its travel.

FIG. 11.

This valve consists of an arched metal plate, accurately planed and fitted (Fig. 11), which slides over another plate cast on to the cylinder, with which it communicates by means of two passages, *a*, *b* (Fig. 12).



FIGS. 12 and 13.

A third passage *c* leads to the condenser, or is open to the atmosphere. The cast-iron plate is accurately planed, and is covered by a steam chest connected with the boiler. The slide valve must never at any point of its travel allow steam from the boiler to pass direct into the exhaust passage *c*; but as it travels it opens the *steam ports* *a* and *b* alternately, and allows steam to pass from the steam chest into the cylinder. The slide valve is so designed that when steam is admitted through the port *a* to one side of the cylinder piston the other port *b*, which communicates with the other side of the piston, is put into communication with the interior of the slide valve, so that the steam contained on that side may escape through the exhaust port *c*.

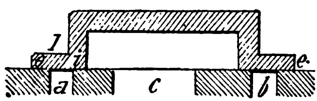


FIG. 14.

Fig. 14 shows an ordinary slide valve on its *valve seat* at a point midway in its travel. Fig. 13 shows a plan of the three

ports, a, b, and c. The widths e and i, by which the edges of the valve overlap the edges of the ports, are called outside and inside *lap*. Without laps it would be impossible to expand steam, because immediately the valve had closed one port, a for instance, it would put it into communication with the exhaust c.

To admit steam at the beginning of the piston stroke, if there were no lap, the slide valve would have to be at its dead centre at that very moment, and this would mean that the eccentric would have to be set at 90° to the engine crank.

On account of the lap e the eccentric must be fixed so that its radius makes a greater angle than 90° with the crank. Let us call this angle of advance δ, then the angle formed by the crank and the centre line of the eccentric will be $90° + \delta$.

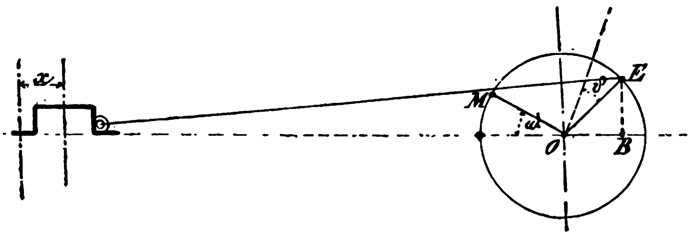


Fig. 15.

In order to fix the dimensions of the slide valve, it is necessary to know the position it will occupy compared with its mean position, with reference to the various positions of the piston with an eccentric of given radius. Zeuner's diagram shows how this can be done.

Zeuner's Diagram.—Fig. 15 shows the slide valve at a distance x from its midway position. Let ω represent the angle through which the crank has passed from commencement of stroke of piston and δ the angle at which the eccentric is set, then x will equal OB, so that

$$x = OB = r \sin OEB = r \sin (\omega + \delta),$$

or

$$x = r \sin \delta \cos \omega + r \cos \delta \sin \omega.$$

If

$$r \sin \delta = A$$

and

$$r \cos \delta = B,$$

we shall have

$$x = A \cos \omega + B \sin \omega.$$

This equation represents in polar co-ordinates two tangential circumferences of equal radii, and whose diameters are at an angle δ with the perpendicular to the direction of the crank at the dead centre.

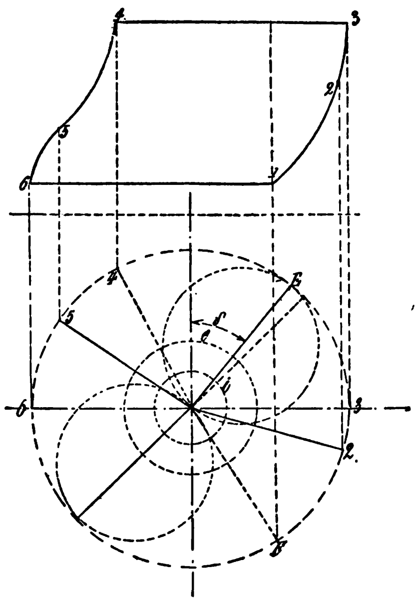


FIG. 16.

Let us set out these two circumferences, as shown on Fig. 16, and from the point o set out radii corresponding to the various positions of the crank. The lengths intercepted by the circumferences will represent the displacement of the slide valve. If from the point o as centre we describe two circles whose radii are respectively equal to the outside lap e and to the inside lap i, the intersection of these two circles with the two others already drawn will fix the exact positions of the crank corresponding to the admission, expansion, and exhaust of the steam. Fig. 16 shows the method adopted to fix all the stages of a cycle by means of

Zeuner's diagram. The opening of a steam port will be represented by

$$h = x - e,$$

and the opening of the same port to the exhaust by

$$K = x - i.$$

The ports must always be designed so as not to choke the steam as it enters the cylinder, the velocity of admission being taken at 25 metres per second.

Any valve motion can be designed by means of Zeuner's diagram. We will not dwell upon this point, but will refer any reader desirous of going more deeply into the matter to special works which have been written on the subject.

Steam Generators.—We will now say a few words about steam generators to conclude our general description of the steam-engine.

The least complex boiler (without doubt) is the old longitudinal boiler heated from without. By giving it sufficient length its efficiency can be made at least equal to that of other types of boilers, but it has the great disadvantage of taking up too much room, and is consequently not adapted for the purposes of road locomotion.

The tendency is, of course, to get very light boilers, which steam well for a small volume. Tubular boilers give the best results from this point of view, and can steam from 100 to 120 kilos of water per square metre (20·5 to 25·6 lbs. per square foot) of heating surface at a pressure of 7 atmospheres, whereas boilers with inside fire boxes of the *Lancashire* type only steam about 35 kilos of water per square metre (7 lbs. per square foot) of heating surface. An ordinary locomotive boiler is shown in Fig. 17. To have a strong boiler the thickness of the plates forming the shell should be calculated from the following formula, prescribed by official regulations:[1]

$$e = 1{\cdot}8d\,(n - 1) + 3,$$

[1] In France.

e being the thickness of the plates in millimetres, *d* the diameter of the shell in metres, and *n* the number of absolute atmospheres in the boiler.

We have already said that all well-proportioned boilers have about the same efficiency, and produce from 8 to 9 lbs. of steam per lb. of fuel.

The total heating surface of the boiler must therefore be calculated according to the number of lbs. of steam required per hour for the motor on the basis of a steaming power of 100 kilos per hour per square metre (20·5 lbs. per square

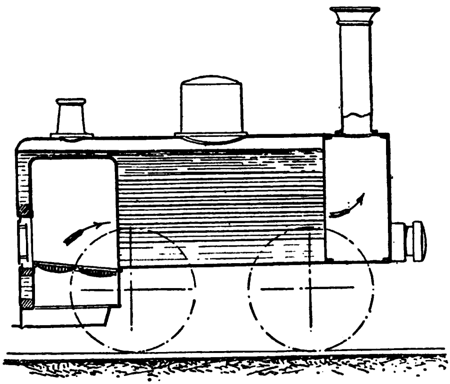


FIG. 17.

foot) for boilers of the locomotive type. Once the total heating surface is known, the grate area can be made about one-thirtieth. This area can be calculated exactly by assuming that about 70 kgs. of coal per hour per square metre (14·3 lbs. per square foot) is burnt with ordinary draught and 135 kgs. (27·7 lbs.) with forced draught.

We will not dwell any longer upon this subject, as we shall have to refer to it when dealing with special types of boilers, such as those of Messrs. de Dion & Bouton and of Mr. Serpollet, which have been specially designed for road locomotion. We will now pass on to petroleum gas motors.

Gas Motors.—The working of a gas motor can easily be understood.

Let us suppose that by some process we fill a cylinder with a mixture of carburetted air, or a mixture of gas and air, in such a proportion as to obtain an explosive charge; then, by causing an explosion with an electric spark or other means, the gas mixture is instantaneously raised to a very high temperature and to a correspondingly high pressure. The piston, which previously confined the gas to one side of the cylinder, will be driven forward till the pressure acting on it falls, owing to the increase in volume of the hot gases caused by the travel of the piston, nearly to atmospheric pressure.

On the return stroke the burnt gases will be driven out, and by recharging the cylinder with another supply of explosive mixture the piston will again be driven forward.

The cycle we have just described can be obtained by admitting the explosive mixture into the cylinder at the commencement of the stroke of the piston by means of a special compressor. Motors of this type are called *single-cycle motors*, the charge being exploded for every revolution of the crank. In this case the gas can be admitted at atmospheric or even higher pressure before the explosion. Hence two new subdivisions.

In most of our present motors the gas is compressed by first drawing in the mixture during the whole of the forward stroke of the piston, and by compressing it during the return stroke, the explosion only taking place when the piston starts on its second forward stroke. The different stages of this cycle are as follows:—

First forward stroke: drawing in of charge.

First return stroke: compression of charge.

Second forward stroke: explosion and expansion.

Second return stroke: expulsion of burnt gases.

The stroke of the piston during explosion and expansion

is the only useful one of the four, and is typical of *Otto-cycle motors*, which, like the *single-cycle motors*, can have the explosive charge previously compressed or not.

Otto-cycle motors with compression before admission are used to a greater extent than the others.

The gas motor has undoubted advantages over the steam motor, as it enables one to do away with a heavy and cumbersome generator, namely, the boiler. The first stage in Carnot's cycle, the production of a certain volume of steam at constant pressure, takes place in the boiler, whereas, with gas motors, it takes place, as described above, in the cylinder of the motor, and, as the operation is almost instantaneous, there is practically no loss of heat. It follows, therefore, that if the cycle of the hot gas were to convert all the available energy into work the efficiency of the motor would approach perfection.

Unfortunately this is not the case, as the gas has a very high temperature, and it is necessary to cool the cylinder with water in order to be able to lubricate it properly. This causes a loss of heat, which may amount in some cases to 50 per cent. of the total heat available. On the other hand, the burnt gas is still at a high temperature even when its pressure has fallen to atmospheric pressure, and its expulsion at this temperature, which is about 1000° centigrade absolute temperature, is another source of loss.

After explosion the gas attains a temperature of 2000° absolute, so that if it is expelled at 1000° we have again a loss of 50 per cent. of the total heat available.

At first sight one might be led to think that a loss of 50 per cent. on one hand and of 50 per cent. on the other would leave no heat whatever available for work. This is not the case, however, as the 50 per cent. of heat lost during expulsion is 50 per cent. of what remains after the heat lost due to the cooling process has been deducted; in other words, 25 per cent. of the total heat available. Let Q_t designate the total heat evolved

by the explosion; then the loss due to cooling will be $Q_t \cdot \frac{50}{100}$, so that the heat remaining for conversion into work will only be

$$Q'_t = Q_t - Q_t \cdot \frac{50}{100} = \frac{Q_t}{2}.$$

The 50 per cent of this heat Q'_t is carried away by the heated gas, and the heat convertible into work will become

$$Q_u = \frac{Q'_t}{2} = \frac{Q_t}{4} = 25 \text{ per cent. of } Q_t.$$

This result is not attained in practice, however, and an efficiency of 20 per cent. is considered exceedingly good, and is twice as much as we can obtain even with the best type of steam motor.

This advantage is owing to the absence of boiler, as the latter rarely has a greater efficiency than 50 per cent. Assuming for one moment the losses inherent to steam generators to be nil, the efficiency would be doubled, and we should then get approximately the same result with steam motors as we do with gas and petroleum motors.

By the efficiency of a motor we have hitherto meant the ratio of the heat converted into work to the total heat produced. Part of the work thus obtained is utilised as useful work on the shaft, whilst another portion is absorbed in overcoming the friction of the working parts.

We will call the ratio of useful work on the shaft to the total theoretical work available the *mechanical efficiency* of the motor. Let μ_0 be this new efficiency, W_t the work theoretically available, and W_u the useful work, then we obtain:

$$\text{Mechanical efficiency} = \mu_0 = \frac{W_u}{W_t} = \frac{W_t - W_p}{W_t},$$

W_p being the loss of energy due t friction.

If μ_c represents the heat efficiency of the motor and W_T he total energy obtained by the combustion of the gas, then

$$\mu_c = \frac{W_t}{W_T},$$

so that the useful efficiency μ_u will be

$$\mu_u = \frac{W_u}{W_T} = \frac{\mu_0 W_t}{\frac{W_t}{\mu_c}} = \mu_0 \mu_c.$$

One sees at once that the useful efficiency of a motor is equal to the heat efficiency multiplied by the mechanical efficiency. The latter varies very little, and depends entirely on the quality of the workmanship of the motor. The heat efficiency, however, can be largely increased.

One of the best devices hitherto adopted to obtain this increase of efficiency is to compress the gas considerably just before explosion. We can see at once the advantages of this *isothermal* compression.

Let v be the volume of the gas at the time of explosion, P its pressure, and Q the heat it evolves in combustion. If the compression has been isothermal, the final temperature and resulting pressure will be the same, whatever the degree of compression. The greater the compression of the charge at constant temperature the greater will be its pressure P.

Again, we know that the greater the initial pressure the more expansion we can obtain before falling to atmospheric pressure, and consequently the lower will be the temperature of the escaping gas, so that less heat will be carried away and lost.

An adiabatic compression has not the same advantages, because the compression raises the temperature of the gas before explosion, so that when the latter takes place the temperature is higher than if the gas had not been compressed.

Otto-cycle motors have this drawback, because the gas is compressed in the cylinder, which, being itself at a high temperature, consequently increases that of the gas before explosion.

As in steam-engines, there is every advantage in increasing the speed of the motor so as to reduce the loss due to the

action of the walls of the cylinder. Evidently the less contact there is between the heated gas and the walls of the cylinder the less heat will be carried away by the water of circulation. But in increasing the speed we must not forget that the loss occasioned by friction increases proportionately, and we may get to a point when the available heat we save is absorbed by the increased friction.

After these few remarks, we will now examine the working of gas motors, and apply the laws of thermo-dynamics already set out in Chapter I.

HEAT STUDY OF GAS AND PETROLEUM MOTORS.

Otto-cycle Motors.—Let us assume (Fig. 18) the piston of the motor to be at the commencement of its first forward stroke, during which it draws in the mixture of gas and air.

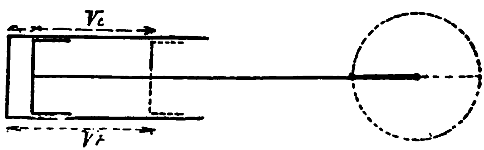


Fig. 18.

Then, if v_0 is the clearance between the piston and the end of the cylinder at commencement of stroke, the process of drawing in the gaseous mixture will be represented by the straight line 1, 2 on the diagram (Fig. 19). The final volume v_t of the gas will be equal to the initial volume v_0 plus the volume v_c swept by the piston during a single stroke. The pressure being nearly equal on both sides of the piston, no work is produced or expended.

It is different on the return stroke, however. There is adiabatic or isothermal compression of the gases, as the case may be, and the energy required for this work must be supplied by the motor itself. The work represented by the area 1, 3, 2 is therefore negative. Sometimes the gas is only

compressed at a certain point on the return stroke, so that the compression is shown on diagram by the dotted line 2′ 3′ instead of by the curve 2, 3.

We will, however, assume in the following that compression takes place, as is generally the case, at the beginning of the return stroke.

The work required for an isothermal compression is (Chap. I. p. 8)

$$(21) \qquad W_c = p_0 v_t . \log_e \frac{v_t}{v_0}.$$

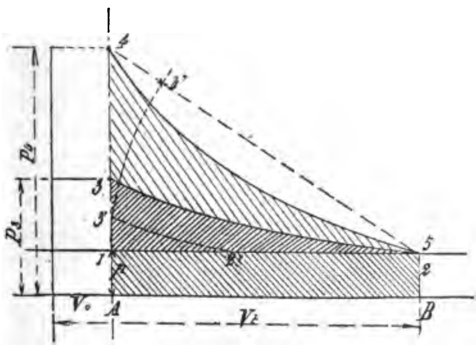


FIG. 19.

For an adiabatic compression it becomes

$$(22) \qquad W_c = \frac{p_0 v_t^{\gamma}}{1-\gamma}\left(v_t^{1-\gamma} - v_0^{1-\gamma}\right) \text{ (adiabatic).}$$

v_t and v_0 being known quantities, the value of W_c is easily found in both cases.

For an isothermal compression the resulting pressure at point 3 will be

$$(23) \qquad p_3 = \frac{p_0 v_t}{v_0} = p_0 \frac{v_t}{v_0};$$

and for an adiabatic compression we shall find from the equation

$$p_0 v_t^{\gamma} = p_3 v_0^{\gamma}$$

that

(24) $$p_3 = p_0 \left(\frac{v_t}{v_0}\right)^{\gamma}.$$

In the mixtures generally employed γ is equivalent to about 1·4, so that we see at once that p_3 will have a higher value by adiabatic than by isothermal compression. But, as we have already said, the first method has the disadvantage of increasing the temperature of the gas, so that after explosion the resulting temperature is higher than with an isothermal compression. We can easily find the temperature of the gases at the end of an adiabatic compression by means of equations

$$p_0 v_t = RT_0$$

and

$$p_3 v_0 = RT_3$$

whence

$$\frac{P_3}{P_0} = \frac{T_3}{T_0} \frac{v_t}{v_0}.$$

And as, from equation (21),

$$\frac{P_3}{P_0} = \left(\frac{v_t}{v_0}\right)^{\gamma},$$

the former expression becomes

$$\left(\frac{v_t}{v_0}\right)^{\gamma} = \frac{T_3}{T_0} \left(\frac{v_t}{v_0}\right),$$

or

$$\frac{T_3}{T_0} = \left(\frac{v_t}{v_0}\right)^{\gamma-1};$$

and therefore

(25) $$T_3 = T_0 \left(\frac{v_t}{v_0}\right)^{\gamma-1}; (\gamma = 1.\ 4).$$

This equation enables us to calculate T_3 as a function of v_t, v_0, and T_0, all of which are known quantities.

Equations 22, 23, 24, and 25 consequently enable us to calculate all the steps of the compression—that is, the work of

compression, the final pressure, and the final temperature, so that point 3 is absolutely fixed.

Explosion and expansion of the gas takes place during the second forward stroke, corresponding to the third stage in the cycle. The explosion is not quite instantaneous in practice, so that v_0 is not the abscissa of point 4, as shown on the diagram (Fig. 19). Point 4 will be more or less distant from the perpendicular dropped from 3, according to the rapidity of explosion and speed of the piston, and it may, for instance, be at 4′.

This disturbance of the theoretical cycle varies with each separate motor, so that we cannot, of course, take it into consideration, but must calculate the final pressure and temperature after explosion as if it were instantaneous.

Under these circumstances the work done during explosion is nil, as the piston has not moved, and the heat evolved has only increased the internal energy of the mixture.

Let Q be the amount of heat evolved per kilogramme of explosive mixture, T_4 the final temperature, and P_4 the final pressure, then

$$(T_4 - T_3)C_v = Q. \tag{26}$$

T_3 is known, and C_v, the specific heat of the mixture can be found from

$$C_v = 0{\cdot}172 + 0{\cdot}0000492\ T_4.$$

So that, by substitution,

$$(T_4 - T_3)\,(0{\cdot}172 + 0{\cdot}0000492\ T_4) = Q \tag{26′}$$

the heat evolved Q depends upon the quality of the mixture. For ordinary lighting gas mixed with 6 volumes of air, $Q = 574$ calories.

If we proceed by isothermal compression, then, assuming the surrounding air to be at a temperature of 15° C., or 288° absolute, the above equation is modified:

$$(T_4 - 288°)\,(0{\cdot}172 + 0{\cdot}0000492\ T_4) = 574^{\text{cal}},$$

which, on being worked out, becomes

$$T_4 = 2298°.$$

We will take a numerical example further on for an adiabatic compression.

We notice, with M. A. Witz, the author of an interesting work on the steam-engine, that after combustion the gas is contracted in the proportion of 142 to 148, which diminishes the final pressure to a corresponding extent.

Therefore, designating the final pressure of the gas after explosion by P_e, and assuming there is no initial compression, we find

$$P_e = \frac{142}{148} \frac{RT_4}{v_0}, \tag{27}$$

and, as

$$P_3 v_0 = RT_3,$$

we shall have

$$v_0 = RT_3$$

when $P_3 = 1$.

By substitution, equation (27) becomes

$$P_e = \frac{142}{148} \frac{T_4}{T_3} = \frac{142}{148} \cdot \frac{2298}{288} \cdot = 7{\cdot}62^{\text{atm}}.$$

Multiplying P_e by the amount of compression $\frac{P_3}{P_0}$, we obtain P_4, the pressure at the end of the explosion :

$$P_4 = \frac{P_3}{P_0} \cdot \frac{142}{148} \cdot \frac{2298}{288} = \frac{P_3}{P_0} \cdot 7{\cdot}62^{\text{atm}}. \tag{28}$$

Assuming the ratio of compression to be equivalent to 3, then

$$P_4 = 22{\cdot}86^{\text{ atm}}.$$

The pressure never attains this value in practice with the amount of compression we have taken, because the explosion is not instantaneous, and heat is absorbed by the cold walls of the cylinder.

After explosion the pressure of the gas must be reduced as much as possible to atmospheric pressure by expansion, which can be considered adiabatic on account of the low specific conductivity of the gas in question.

The gas must therefore have a pressure P_0 for a final volume v_t so that

$$P_4 v_0^{\gamma} = P_0 v_t^{\gamma}$$

or

$$\left(\frac{v_t}{v_0}\right)^{\gamma} = \frac{P_4}{P_0};$$

whence

(29) $$v_t = v_0 \left(\frac{P_4}{P_0}\right)^{\frac{1}{\gamma}}.$$

If there is no initial compression, then

$$v_t = v_0 (7 \cdot 6)^{\frac{1}{1 \cdot 4}} = v_0 \,.\, 7 \cdot 6^{\,0.715} = 3 \cdot 9 \,.\, v_0\,;$$

and with a pressure of 3 atmospheres

$$v_t = v_0 . (22 \cdot 8)^{0.715} = 8 . v_0.$$

The temperature can be found from equation (25), as in the case of an adiabatic compression:

$$T_4 = T_5 \left(\frac{v_t}{v_0}\right)^{\gamma - 1}$$

$$T_5 = T_4 \left(\frac{v_0}{v_t}\right)^{\gamma - 1}$$

If the gas had not been compressed, we should have had:

$$T_5 = 2298. \left(\frac{1}{3 \cdot 9}\right)^{0.4} = 1200°.$$

And with a compression of three atmospheres

$$T_5 = 2298. \frac{1}{8}^{0.4} = 820°.$$

The above figures clearly demonstrate the advantages of a preliminary isothermal compression. It is not all gain, however, as we must remember that negative work was required to

compress the gas, and this may, in some cases, as we shall see later on, cancel the advantage of being able to expel the burnt gas at a lower temperature. As in road locomotion, high power and small volume are required before all, and economy is a secondary question; so we must, in such a case, have preliminary compression. The work done per stroke of piston is practically proportional to the amount of compression, or, in other words, to the volume of gas expended, all other things being equal.

Equation (22) might enable us to find the work done by an adiabatic expansion:

$$W_d = \frac{p_0 v_t^\gamma}{1-\gamma}\left(v_t^{\,1-\gamma} - v_0^{\,1-\gamma}\right);$$

but as the external work produced is entirely due to the change in the internal energy of the gas, it is easier to say that

$$W_d = U_4 - U_5,$$

and as the energy of a gas is a function of its temperature alone, we have

$$W_d = C\,(T_4 - T_5). \tag{30}$$

C is almost a constant, and equivalent to $a + \frac{bR}{2}(T_4 - T_5)$ for the mixture under consideration. a and b are given in the tables at the end of this chapter. We find, therefore, that *the work done per unit weight of gas varies inversely with the temperature of the expelled gas, and directly with the temperature of the gas at the end of the explosion.*

Unfortunately we cannot have exceedingly high temperatures in practice, and, as already pointed out, we are even obliged to cool the cylinder, so that the motor may be lubricated and work well. Again, we cannot decrease the temperature of the expelled gases below a certain limit (about half that of the temperature at the end of explosion) without lowering this temperature below that of the atmosphere. Even theoretically,

then, the loss due to heat carried away by the gaseous mixture amounts to half the total heat available.

From the preceding we can easily find the heat efficiency of an Otto-cycle motor with preliminary adiabatic compression.

It is expressed as follows :

$$\mu_c = \frac{\text{Useful heat} - \text{Work of compression}}{\text{Total heat}}$$

$$(31)\quad \mu_c = \frac{\left[a + \frac{bR}{2}(T_4 + T_5)\right](T_4 - T_5) - \left[a + \frac{bR}{2}(T_3 + T_0)\right](T_3 - T_0).}{\left[a + \frac{bR}{2}(T_3 + T_4)\right](T_4 - T_3)}$$

The expression $a + \frac{bR}{2}(T' + T'')$ represents the specific heat of the mixture. Assuming that this specific heat does not vary with the temperature, then equation (28) becomes :

$$(28)\qquad \mu_o = \frac{(T_4 - T_5) - (T_3 - T_0).}{(T_4 - T_3)}$$

This formula suffices in many cases for estimating the efficiency which one may expect.

There is never any isothermal compression in Otto-cycle motors. It requires a special compressor, so that the motor then becomes a single-cycle motor.

In that case we find the work of compression from

$$W_c = p_0 v_t \log_e \frac{v_0}{v_t},$$

and this must be multiplied by $\frac{1}{425}$ and the result deducted from the useful heat in order to get at the efficiency.

Excepting that their mechanical efficiency is slightly less, single-cycle motors are in every respect similar to Otto-cycle motors. The former can compress gases to any required extent, whereas this is difficult with the latter, in which the compression generally takes place at the commencement of the

return stroke of the piston. The single-cycle motor can also give twice as many explosions as an Otto-cycle motor, speed for speed, and will therefore be twice as powerful, volume for volume, if the space taken up by the compressor be neglected.

In short, we have the same process as in the Otto-cycle motor, with the exception that the gas is drawn in and compressed in a separate cylinder. There is no need to recapitulate the different stages, which we have already explained in detail.

The tables at the end of the chapter are drawn up for the purpose of calculating the theoretical amount of work available in any motor for different qualities of explosive mixture. The calculations we have gone into can even be avoided in many cases by using these tables.

To make matters quite clear, however, we will work out a numerical example, and give a practical application of our formulæ.

Let us take a motor with a preliminary isothermal compression of 3 kgs. per square centimetre, and suppose we require 10 horse-power of useful work with a velocity of 500 revolutions per minute.

The power per revolution will be :

$$W_u = \frac{10 \times 75^{km}}{500} \times 60 = 90 \text{ kilogrammetres.}$$

We may estimate that the average consumption for this type of motor per horse-power per hour is about 700 litres of gas, having a heat of combustion of 573·7 calories per kilogramme of mixture (1 volume of ordinary lighting gas with 6 volumes of air).

The total volume of explosive mixture is therefore

$$700 \text{ litres of gas} + 4200 \text{ litres of air} = 4900 \text{ litres,}$$

and the weight is

$$4200 \times 1{\cdot}25^{gr.} + 700 \times 0{\cdot}13 = 5250 + 91 = 5341^{gr}.$$

Therefore, for every stroke of the piston—that is, for every

revolution—we must admit a volume of gas into the cylinder equal to

$$\frac{4900 \times 10 \text{ H.P.}}{500 \times 60} = 1{\cdot}63, \ l$$

or, in weight,

$$\frac{5341 \times 1{\cdot}63}{4900} = 1{\cdot}78 \text{ gramme of mixture.}$$

The heat evolved by 1·78 gramme of explosive mixture is equivalent to :

$$\frac{573{\cdot}7}{1000} \times 1{\cdot}78 = 1{\cdot}02^{\text{cal}}. = 435 \text{ kgm.}$$

The theoretical work available is, in round numbers, 435 kilogrammetres, and, as we cannot obtain more than 90 kilogrammetres of useful work, we see at once that we only get about 20 per cent. of the total energy available, which is the estimate we came to at the beginning of this chapter.

The volume occupied by 1·63 litre of explosive mixture when compressed isothermally at 3 atmospheres will be

$$V_0 = \frac{1{\cdot}63}{3} = 0{\cdot}543^{\text{lit}} = 0{\cdot}000543^{\text{m3}}$$

for

$$P_3 = 30{,}000 \text{ kgs. per square metre.}$$

Assuming the temperature of the compressed gas to be $273 + 15 = 288°$ absolute, equation (26) gives :

$$(T_4 - 288)\,(0{\cdot}172 + 0{\cdot}0000492\, T_4) = 573°$$
$$T_4 = 2298° \, ;$$

and, substituting the values of T_4 and $\frac{P_3}{P_0}$ given in equation (28), we obtain

$$P_4 = 3 \,.\, \frac{142}{148} \,.\, \frac{2298}{288} = 22{\cdot}86^{\text{atm}}.$$

In practice, however, we only consider half the heat of explosion of the mixture to be available, on account, as we have already said, of the cooling caused by the walls of the

cylinder and the fact that the explosion is not instantaneous, so that we must assume in our calculations that P_4 has only half the above value ; so that

$$P_4 = 11{\cdot}5 = 11{,}500 \text{ kilogrammes per square metre.}$$

In this case the total volume v_t of a cylinder full of gas will be given by equation (29),

$$v_t = v_0 \left(\frac{P_4}{P_0}\right)^{\frac{1}{\gamma}}$$

$$v_t = 0{\cdot}000543^{m3}, \ (11{\cdot}5)^{\frac{1}{1{\cdot}42}} = 5 \times 0{\cdot}000543 \text{ about}$$

$$v_t = 0{\cdot}002715^{m3}.$$

Equation (25) enables us to calculate the temperature T_5 of the gas at the end of expansion :

$$T_5 = T_4 \left(\frac{v_0}{v_t}\right)^{\gamma-1}$$

$$T_5 = 1149 \left(\frac{1}{5}\right)^{0{\cdot}42} = 1149 \ \frac{1}{2{\cdot}4} = 500^\circ \text{ about.}$$

We have given T_4 half its theoretical value to allow for cooling due to the walls of the cylinder, which accounts for T_5 being so small, although it is in strict accordance with practical experience. Even lower temperatures than these often result if a good circulation of cold water is kept up around the cylinder. Of course this method of lowering the temperature of the gas has no advantage whatever from the point of view of heat efficiency. If less heat is carried away by the hot gas, the reason is that it has already been absorbed by the circulating water, and, moreover, the consequent lowering of temperature reduces the amount of expansion possible.

We can find the work done by the expansion of 1 kilogramme of gas by means of equation (30),

$$W_d = C\ (T_4 - T_5)$$

$$W_d = \left[a + \frac{b}{2} R\,(T_4 + T_5)\right](T_4 - T_5)$$

$$W_d = \left[0{\cdot}16 + \frac{0{\cdot}000038}{2}(2298 + 1000)\right](1149 - 500) = 154^{cal}.$$

But as we only have 1·78 gramme of gas, the work done will be

$$W_d = \frac{154}{1000} 1{\cdot}78 = 0{\cdot}278^c = 117 \text{ kilogrammetres.}$$

In conclusion, let us find the work done by compression W_c:

$$W_c = P_0\ 3.\ V_0 \log_e . \frac{\nu_t}{\nu_0}$$

$$W_c = 10000 \,.\, 3 \,.\, 0{\cdot}000543 \,.\, \log_e 3$$

$$W_c = 18{\cdot}46 \text{ kilogrammetres.}$$

By deducting the above from W_d we get the amount of work available, and if the latter be multiplied by the mechanical efficiency of the motor in question we finally obtain the useful work on the shaft:

$$W_u = (117 - 18{\cdot}5)\ K_0.$$

Assuming this mechanical efficiency to be 0·95, we arrive exactly at the power which our motor had been designed to supply:

$$W_u = 90 \text{ kilogrammetres.}$$

This bears out our equations and our allowances for loss of heat in a gas motor.

VALVE MOTION.

The supply and exhaust of gas can be effected by means of valves in the same manner as with steam motors. Ordinary valves are generally adopted, as they are almost air-tight.

The design of valve motion is extremely simple from a kinematic point of view. There is no need, as with steam motors, to employ Zeuner's diagram to find the point of cut-off and the amount of lead required.

All we have to do is to so arrange matters that the admission valve shall be lifted at a certain point in the travel of the piston, and shall drop upon its seat when explosion is about to take place, and that another valve, which allows the gas to

pass out, shall remain open during the return stroke of the piston.

These two operations are characteristic of a *single-cycle motor* with compression in a special cylinder, and they are effected by means of cams on the motor shaft. Fig. 20 shows an arrangement for carrying this out. The rod *a*, working the admission valve, is raised by the cam *A* during a short interval of time represented by the angle *α*. The cam *E* is arranged, as shown on sketch, to raise the rod *e*, which opens a valve at the end of the up stroke of the piston, and to keep it

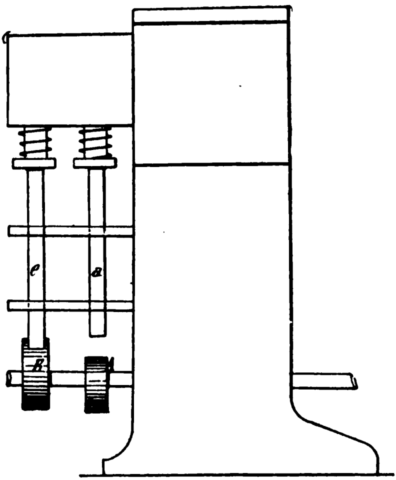


Fig. 20.

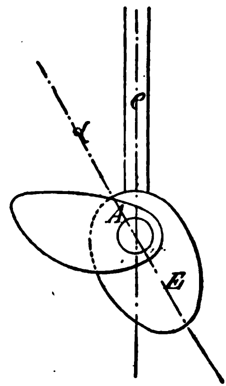


Fig. 21.

so raised during the whole of the down stroke. The valves are provided with springs to bring them back quickly on to their seats.

A similar arrangement can be adopted for the valves of Otto-cycle motors, but only the cam working the exhaust valve can be used. The other valve works automatically; when the piston has driven out the burnt gases the suction of the piston as it leaves the bottom of the cylinder is sufficiently strong to

overcome the resistance of the spring which keeps the valve on its seat and to draw in the necessary amount of gas for the succeeding explosion. This admission valve closes automatically on the return stroke, and the gas is compressed till explosion takes place.

We shall have to return to the subject of valve motion, and describe the systems adopted, when we speak of auto-cars.

Ignition.—Explosion may be produced in three different ways :—

1. By a flame.
2. By an incandescent tube of platinum.
3. By electricity.

The first system is the oldest, is fairly good for stationary motors, but is little used for hauling motors.

The second method, by means of incandescent platinum, is, on the contrary, very much adopted. A tube of platinum is enclosed in an air-tight box, which forms part of the cylinder body. This box can be made to communicate at the moment of igniting with the inside of the cylinder by means of a valve. The platinum tube, which is carried through the sides of the box, is heated to red heat by means of a special burner. This arrangement gives excellent results and seldom fails. It, however, requires a special burner and an additional valve, both of which are drawbacks. Neither can it be used with the very high temperatures which, as we have seen, are essential to rapid explosion.

The third system is far the best under this head. The electric spark is itself at a very high temperature, and with this method of ignition no additional valve is required.

Two cells, or two small accumulators, a Ruhmkorff coil, a commutator fixed to the shaft, and a porcelain tube carrying the two wires into the cylinder are all that is required to produce a spark. This system of ignition is much preferred to the other two on account of its simplicity, and it is always adopted for small motors of less than 2 horse-power, where

great simplicity is necessary. This system, however, requires great care to keep clean, as tar and other impurities deposited in the cylinder may cause the spark to fail by short circuiting the wires. This is its only weak point, which, however, can be minimised by using a powerful coil. We shall have occasion to refer again to the details of this method of ignition.

ACCUMULATORS AND ELECTRIC MOTORS.

It is impossible, in the space allotted to us, to give even a slight notion of the application of electricity to traction. We

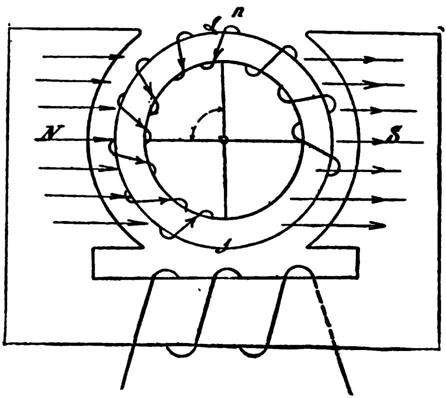


Fig. 22.

shall therefore not attempt to do so, but merely give the general principles upon which electric motors are built, pointing out the advantages and disadvantages, so that the reader shall not be led to expect more from electricity than it can give. How many people does one meet who, seeing that a car is being *propelled by electricity*, expect it to run quickly and to be light and easy to work, and imagine that only a few accumulators or batteries, a mere nothing, are required to supply the necessary power.

Working of an electric motor.—An electric motor con-

sists of two main parts, the armature and the carcase (Fig. 22). The armature is generally ring-shaped, and isolated copper wires are rolled round it in spirals, as shown on figure. The carcase is excited by a coil through which an electric current is passed. This produces a *magnetic field* between the poles N and S. On sending an electric current through the wires which are rolled round the armature in the direction shown on figure the armature would begin to revolve in the

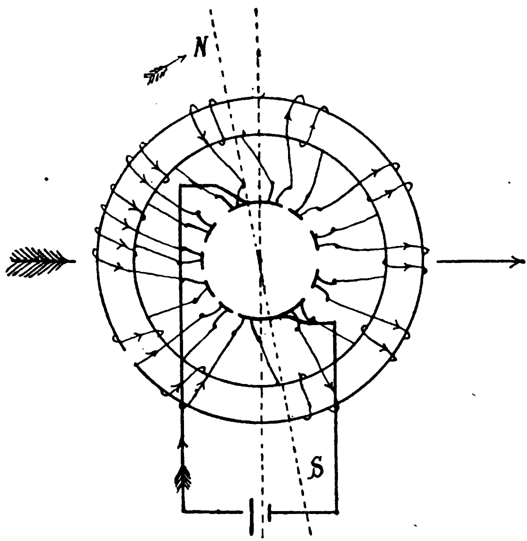


FIG. 23.

direction shown by arrow, on account of the magnetic field NS acting on the current passing through the armature.

Fig. 23 shows the arrangement adopted so that the current passing through the coils to the right and left of the line NS shall always have the same direction, notwithstanding the rotation of the ring. Each spiral is connected with the blade of a collector, K, and, by means of two brushes fitted to it in the direction of the line NS, the current passing through

these two brushes has always the same direction in both halves of the armature. In practice the brushes are set back at an angle a from the line NS. The only thing now required to obtain work is to fix the armature to a shaft and to connect the brushes and ends of the wire wound round the carcase to a generator of electricity.

The loss of energy in electric motors is chiefly due to: first, the conversion of electric energy into heat in the wire wound round the carcase and round the armature; second, loss caused by variation of magnetism in the armature. For instance, a given section of the ring is subjected during each revolution to magnetic action, equal but acting in opposite directions, and this entails two kinds of losses—loss by Foucault's current and loss by hysterisis. The first is occasioned by infinitely minute electric currents, generated in the wires and in the core of the armature, which *are converted into heat, and consequently absolutely lost*; loss by hysterisis is due to the inertia of the iron to change its magnetism. A third loss of energy is due to friction of shaft on its bearings.

The above losses, excepting that due to hysterisis, can be reduced to any advisable extent.

The loss due to heating varies inversely with the diameter of wire wound round the armature and carcase, so that, by adopting a suitable section of wire, Foucault's currents may be reduced. The core of the armature must also be of suitable section to avoid the production of Foucault's currents.

In short, by suitably increasing the size of the parts of an electric motor, its efficiency can be increased even as much as 98 per cent.

It follows from this that the motor's efficiency will vary directly with its weight. The only objection to a heavy motor for stationary purposes is its prime cost, but when the motor is applied for haulage purposes it is quite another matter, as the work to be done is proportional to the weight hauled, and

consequently the weight of the motor itself becomes an important factor.

The efficiency of the motors now used for haulage purposes seldom exceeds 80 per cent. for ordinary working, and it is considerably reduced when the motor is called upon, as often happens, to give a higher power than its normal power.

The power per kilogramme, compared with the total weight, may amount to 30 watts, so that the weight of a 10 horse-power motor would be :

$$P = \frac{1 \times 736 \times 10}{30 \times 0{\cdot}8} = \frac{245{\cdot}3^{k}}{0{\cdot}8} = 306 \text{ kgs. (673 lbs.)},$$

a horse-power being equivalent to 736 watts.

The weight of an electric motor is therefore a considerable item, and will often exceed that of a petroleum motor of the same power.

When we calculate the weight of accumulators required to work the motor, we shall find that it exceeds that of the motor itself. For safety and facility in working, an electric car is far preferable to all the other systems. An electric motor can, when required, be made to give twice its ordinary power for some time, so that very high power can be obtained for starting purposes, which no gas or steam motor, with the exception of the Serpollet, can do. The electric car is easily controlled, shows no smoke, and emits no disagreeable smell of burnt oil.

There is, however, one serious drawback to electric cars, which is almost sufficient to condemn their use. We allude to the accumulator.

A large number of appliances have been devised for storing electricity since Planté discovered that after passing an electric current through two lead plates immersed in a solution of water and sulphuric acid he could get back from the plates part of the work done in the electrolysing process.

The principle has, however, remained unchanged, and we

still employ lead plates as electrodes and very dilute sulphuric acid as electrolyte for our accumulators.

The electromotive force required to charge these accumulators is always about 2·5 volts per element, but only 2·10 volts can be got back on an average.

An accumulator can return about 90 per cent. of the electricity stored, on condition that the current discharged does not exceed a certain amount per unit of surface of lead plate. If the strength of the current discharged be high, the efficiency is not so good. The above 90 per cent. of electricity, however, being returned at a lower potential than the initial potential of charge, the efficiency from the point of view of available energy rarely exceeds 75 or 80 per cent.

This loss of 20 per cent. is important, especially when one considers that the efficiency of an electric motor rarely exceeds 80 per cent., so that not more than 60 per cent. of the power expended by the dynamo in charging the accumulators is returned by the latter.

Multiplying this 60 per cent. by the efficiency of the dynamo, which we assume to be 90 per cent., we find that the actual work done on the shaft only amounts to about 54 per cent. of the work done by the gas or steam motor.

This, however, is not the main objection. In auto-cars, where one can never expect to employ as economical a motor as in stationary plant, the great drawback is the weight of the accumulators, which, until now, has been the most serious obstacle to adapting electric motors to haulage purposes. The accumulator required for working two or three consecutive hours at a speed of 12½ miles an hour without recharging often exceeds in weight that of the car and passengers. Consequently half the tractive power is expended in hauling the dead weight of accumulator and motor. Even on well-kept and fairly level tramway lines electric traction with accumulators competes with difficulty with animal traction, and there are some who maintain that it is more expensive. Is it not

perfectly futile, under these circumstances, to try and obtain an auto-car, based on these principles, which has to do more irregular work, climb steeper inclines, and travel along worse roads than in the case of tramway lines? Mr. Jeantaud has succeeded in this, but at what a cost! And who would be wealthy enough to have an auto-car whose accumulators require recharging every day during a longer time than is spent on the road, a process involving great expense, worry, and the necessity of returning to the electric depôt, because electricity cannot be found at other points along the road?

Let us take an example, and suppose that we require to find the weight of accumulators for working a car seating four and having a speed of $12\frac{1}{2}$ miles an hour. We shall not be taking too high a margin if we estimate the horse-power required for bad roads at 4 horse-power, so that the accumulators, which have an efficiency of 80 per cent., will be required to supply 5 horse-power.

Now, accumulators for haulage purposes weigh about 80 kgs. (176 lbs.) per horse-power per hour (including plates, liquid, and ebony box).

The required weight for 5 horse-power and for three hours will therefore be

$$P = 80 \times 3 \times 5 = 1200 \text{ kgs. (2640 lbs.)}.$$

Even supposing that only two horse-power suffices for hauling the car in question, we get a weight of 600 kgs. (1320 lbs.) for the accumulators, which, added to the weight of motor and starting rheostat, makes a total dead weight of 800 kgs. (1760 lbs.).

In the above figures we have assumed that the capacity of the accumulators corresponded to the normal electricity required, but the above weight must no doubt be increased, on account of the higher power required at special times for starting the car and for climbing up steep banks. The Table (p. 64) for tramway traction by accumulators—the trams seating 52—shows that even in the most favourable case the

Cost of Working per Car-mile.

Ten cars are taken, of which two are reserve.

Calculation of Sinking Fund [1]

—		Capital for 10 cars	Capital for 1 car	Rate	Per car-year		Cost per car-day	
A. *Rolling stock.*								
		£	£	per cent.	£	£	£	£
Body, frame, axles, wheels		1,800	180	15	—	27	·0739	—
Motors	electros	600	60	10	6	16	·0430	—
	armature	400	40	25	10			
Gearing	belt stretcher	80	8	10	·8	26·24	·0719	—
	intermediate shaft	120	12	10	1·2			
	Gall wheels	96	9·6	16	1·54			
	toothed pinions	56	5·6	50	2·8			
	Gall frame	540	54	25	13·5			
	cords	32	3·2	200	6·4			
Commutators	circular commutator	160	16·0	10	1·6	2	·0054	—
	battery reverser	40	4	10	·4			
General	six lamps	12	1·2	200	2·4	2·88	·0079	—
	springs	8	·8	10	·08			
	cables	40	4	10	·4			
	oil	—	—	—	—	47·45	·1300	—
	lubrication, brushing	—	—	—	—			
Interest of two reserve cars		—	—	—	—	4·98	·0146	·3467
		3,984	398·4					

B. *Stationary plant.*

2 40-horse-power steam-engines, at £20 per horse-power; 2 boilers; 1 engine working 20 hours out of 24	1,600	160	10	—	16·00	·0438	—
5 dynamos	300	30	10	—	3·00	·0082	—
General: benches	120	12	10	1·2	2·12	·0059	—
General: cable	80	8	10	·8			
General: amp. metres and volt metres	12	1·2	10	·12			
Accumulators: ebony boxes	640	64	6	3·84	89·92	·2462	·3042
Accumulators: 16 tons of positive plates	1,280	128	54	69·12			
Accumulators: „ „ negative „	1,280	128	11	14·08			
Accumulators: wooden boxes	288	28·8	10	2·88			

C. *Motive power.*

4·4 lbs. per horse-power per hour, 20 hours' work, at 18*s*. 8*d*. per ton	£1·472 (per day for 8 cars)	·1840	
Oil	0·32 „ „	·0400	·2240

D. *Staff.*

1 electrician, manager of depôt	0·40	£2·24		
2 engineers	0·56			
2 stokers	0·48			
4 odd men	0·80		·2800	
Drivers			·2512	·5312
				1·4061

£1·4061 per 62 miles (100 kilometres) per day = 5·413*d*. per car-mile.

[1] The ordinary cost of maintenance of cars is not included.

VERMAND.—GAS MOTORS.

Composition of mixture	a	bR	R	$\frac{AR}{a}$	$\frac{bR}{a}$	T (centigrade)	P (atmospheres)	Q (calories)
Mixture with 6 vol.	0·172	0·0000492	30·87	0·422	0·00057	2298	7·62	573·75
„ „ 8 vol.	0·169	0·0000423	30·48	0·423	0·00050	1933	6·50	436·60
„ „ 10 vol.	0·167	0·0000382	30·25	0·426	0·80046	1720	5·719	352·30

MAXIMUM TEMPERATURE (*centigrade*).

Composition of mixture	Iso-thermal com-pression	Adiabatic compression		
		3 atm.	5 atm.	7 atm.
Mixture with 6 vol.	2298	2390	2435	2480
„ „ 8 vol.	1933	2090	2153	2170
„ „ 10 vol.	1720	1875	1920	1979

MAXIMUM PRESSURE (*in atmospheres*[1]).

Composition of mixture	Isothermal compression			Adiabatic compression		
	3 atm.	5 atm.	7 atm.	3 atm.	5 tm	7 atm.
Mixture with 6 vol.	22·86	38·10	53·34	17·20	25·15	32·40
„ „ 8 vol.	19·50	32·50	45·50	15·10	22·35	28·60
„ „ 10 vol.	17·16	28·59	40·02	13·40	19·80	25·80

[1] To find the pressure in lbs. per square inch, multiply by 14·22.

VERMAND.—GAS MOTORS.

Amount of compression	Compression in cylinder		Compression in a separate cylinder	
	Temperature of gases on expulsion (centigrade)	Efficiency	Temperature of gases on expulsion (centigrade)	Efficiency
3 atmospheres . .	1504	0·290	1804	0·536
5 " . .	1325	0·436	975	0·602
7 " . .	1113	0·546	905	0·640

cost of working amounts to 5·443*d.* per car mile. Traction by means of accumulators is therefore comparatively expensive, and can only be adopted for short distances where the accumulators can be charged frequently. The longer the distance the more accumulators will be required, and the dead weight hauled will be proportionately increased. We can only recommend this system of traction for small lines, which is the only case for which it is suitable. The lighter the accumulators the longer can the car go without having to recharge them. To show how the question of dead weight influences economy in traction, we may mention that Mr. Sarcia, of the Madeleine-Saint-Denis Electric Tramway, prefers to have a high rate of discharge for his accumulators, at the risk of diminishing the efficiency of his battery, in order to reduce, as far as possible, the dead weight necessary to supply the required power.

Accumulators can be avoided by employing overhead wires with a trolley, which collects the electricity from the wire and sends it to the motor on the car. This system is very economical, and is adopted, to a large extent, in the United States; and it is to be regretted that it is not employed to a greater extent over here.

We can never have a really practical electric car till we find a light and economical *generator* of power.

We do not believe much in the future prospects of even light accumulators, as they are so liable to get out of order, and require to be recharged at a depôt after running a certain distance.

CHAPTER IV

DESCRIPTION OF THE VARIOUS SYSTEMS OF STEAM TRACTION

THE SERPOLLET GENERATOR.

It is to Mr. Serpollet, perhaps, that we owe the greatest progress in steam locomotion, for by means of his generator we have been enabled to dispense with all boiler fittings, such as water gauges, valves, air gauges, thermometers, etc., which form part of an ordinary boiler. It is the only generator of steam allowed for traffic in large cities in France.

Since it was first brought out this generator has been built in various forms suitable for different purposes, but all these forms are based upon the same principle, which is as follows: A thin stream of water is forced by means of a pump between the sides of flattened metal tubes, which have a very small interval or water space between them, the tubes having been heated to the required temperature.

The water as it passes through the slits in these hot tubes is converted instantaneously into steam, which is used in the ordinary manner either for working the engine or for any other purpose.

The flattening, which is characteristic of the Serpollet tube, has been resorted to in order to avoid the physical phenomenon known as *calefaction*, which, as one knows, may produce a sudden and dangerous pressure, and is nearly always the cause of boiler explosions.

By laminating the water between the sides of the tube, Mr. Serpollet has been enabled to prevent the deposit of water

drops in the spheroidal state, so that the process of calefaction, so to speak, is brought within safety limits.

We must also add that the steam which comes from these tubes is superheated ; that is to say, is heated to a very much higher temperature than the saturated steam, at which temperature it is employed. It follows, therefore, that during the period of admission into the cylinder of the engine the steam in contact with the cold parts of the motor will cool without condensing on its sides. When saturated steam from ordinary boilers is used this phenomenon always takes place, and, as only a portion of the condensed water is revaporised during the period of expansion, all the heat that had been expended in the boiler to convert this revaporised water into steam is entirely lost, from the point of view of work done in the cylinder. This is one of the reasons why a pound of superheated steam produces more work in a motor than a pound of ordinary saturated steam. This superheating, which certain manufacturers obtain by means of special apparatus, is one of the features of the Serpollet generator. The main parts of the Serpollet generator consist of two feed pumps—one, a *hand* pump, *P*, being used to start working by injecting the first drops of water into the generator ; the other, an *automatic* pump, *P′*, worked by the engine itself, and used instead of the hand pump after the first few revolutions of the engine.

The speed of the motor depends upon the amount of steam produced ; that is to say, upon the amount of water injected. This amount is easily regulated by means of a small cock, called a *regulator*, *E*. It is placed between the generator and the pumps, and enables the water pumped by the latter to pass either into the generator alone, into the water tank alone, or partly into the generator and partly into the tank.

In the first case, all the water supplied by the pump is converted into steam, and the engine then works with its maximum power.

In the second case, the generator is no longer supplied

with water, and the water sent by the pump simply returns to the tank ; the engine then does no more work.

In the third case, the injected water goes partly to the generator and partly to the tank.

By varying the regulator between these two extremes one obtains a range of work on the engine from zero to its maximum power.

The above description will easily be understood by looking at Fig. 24, which shows the general arrangement of the steam generator, the pumps, and the regulator.

In road motors, cars, tramways, &c., the driver regulates the work of his engine by means of his regulator.

When, however, the engine works at constant speed, as in the case of stationary engines, instead of a regulator a valve is used, which, at a certain pressure, opens a pipe which leads the water back to the tank, and thus limits the pressure of injection, and consequently that of the steam.

Description of the Serpollet Generator.—The Serpollet tube was first manufactured as follows :—

A round steel or copper pipe 0·19 to 0·47 inch thick was flattened out so as to leave a small slit of about 0·04 inch, which was called the *capillary* space.

This tube was afterwards rolled into a long coil, and the generator consisted of one or more spirals, suitably arranged in rows over the fire-box, and then connected together.

Unfortunately this spiral form was exceedingly difficult to manufacture, and it often happened that the tube became choked up when a vacuum had not been properly obtained inside it.

The shape, also, was not suited to a generator with a large heating surface, so that the power of this apparatus was somewhat limited.

An attempt was next made to substitute straight tubes with flat section arranged in parallel and in layers over the fire-box. These tubes, however, did not offer sufficient resistance

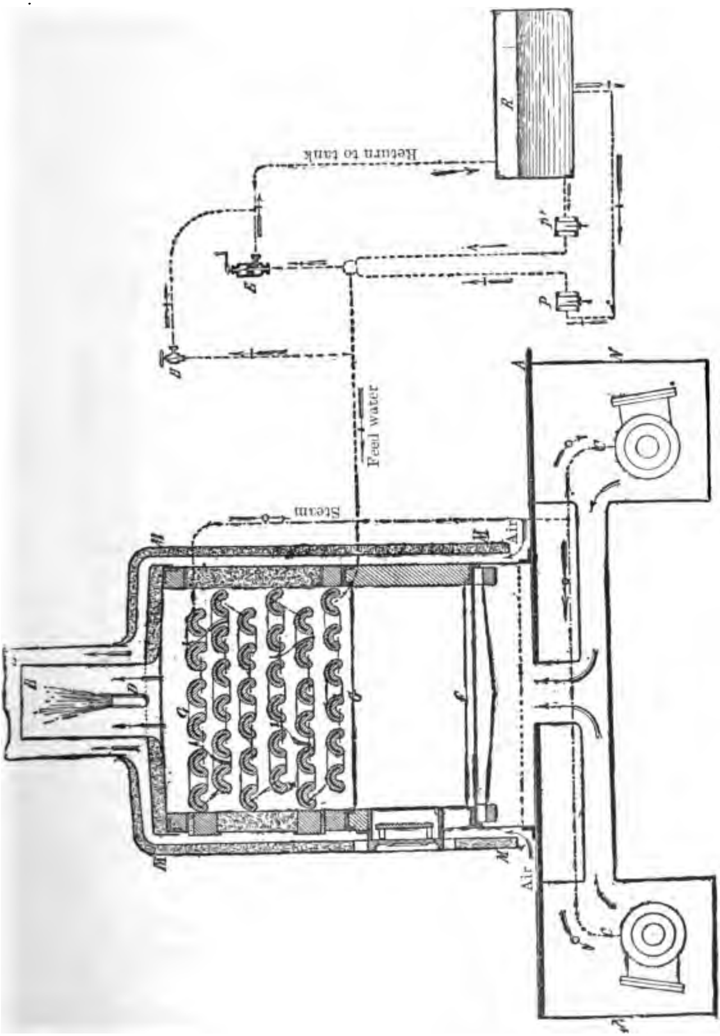


FIG. 24.—Arrangement of the Serpollet Generator.

to the internal steam pressure. The sides were strained in proportion to the leverage exerted by the width of the tube, so that if, through the driver's inattention, the tubes were overheated, the sides bulged out, however well stayed they might be, and the generator was damaged in consequence.

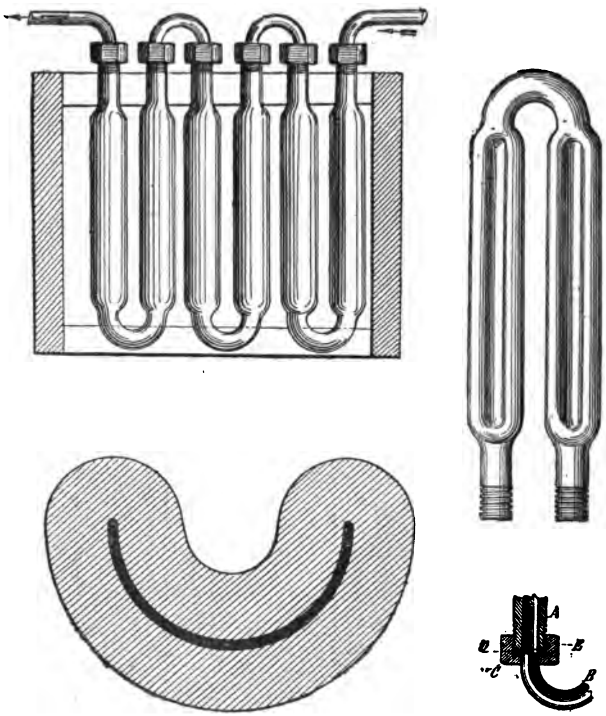


FIG. 25.—Serpollet tube. FIG. 25A.—Joint detail.

To remedy this Mr. Serpollet altered the shape of his tubes, and happily hit upon the idea of giving them a U or gutter section, shown on Fig. 25.

These tubes were coupled in pairs, as shown on Fig. 25, each pair being called a Serpollet element.

This element is formed by a steel tube, originally cylindrical in section, solid drawn in its middle portion and at its two extremities, and stamped by means of a special die in the form of a U in its two intermediate parts. The middle part is afterwards bent, as shown upon Fig. 25A, and the two ends are threaded.

These elements are then placed in a fire-box and so arranged that only the stamped section is exposed to the action of the hot gases, the drawn portions being subjected to a much lower temperature, whilst the threaded ends are placed quite outside the fire-box shell. The elements are then joined together by means of flexible pipes connected to the threaded ends of the tubes by means of nuts.

It is very easy to see that the stamped sides of the new Serpollet tube are no longer subjected to a bending strain, one side being in tension and the other in compression. Theoretically, they may be considered as not liable to get out of shape when cold; practically, they can take pressures of one hundred atmospheres and over, even at very high temperatures.

This has been proved by several official trials, one of which may be given as an example :—One of the extremities of an element was closed, and the other was connected to a test pump. When the element had been heated in a forge fire to a red heat—from 800° to 900° Cent.—water was injected into it, and the pressure attained as much as 170 and even 200 atmospheres, and the tube showed no perceptible distortion. In practice these elements are tested by the Contrôle des Mines of France at 100 and registered at 94 atmospheres.[1]

Besides this advantage of not getting out of shape, the new Serpollet tubes have another very important one: they can be easily grouped together and arranged to suit circumstances so as to give the best heating power. On the other hand, as

[1] French Ministerial order of October 24, 1888.

they can be manufactured in different sizes, and the number employed may be varied, one can obtain a bundle of tubes with a large heating surface capable of producing an abundant supply of steam.

Thus Serpollet generators, which at first could only be used for 2 and 3 horse-power motors, are now used for 50 horse-power, and even over, and, instead of only being able to work a small tricycle of 660 lbs. (1888), they can haul tramway-trains weighing over 2 tons.

The above description will show at once the advantages of the Serpollet generator for traction purposes.

Its construction is very simple, and it requires, as we have said, neither pressure gauge, valve, nor water gauges.

It is also extremely strong, and can give very high power in emergency; for instance, the generator can easily be made to produce three or four times the ordinary working pressure for a sufficient time to enable it to easily climb a very steep bank or get out of a rut.

There is very little danger of incrustation in the tubes on account of the rapidity with which the steam passes through them, but if this should happen, owing to much lime in the water, they can easily and rapidly be taken to pieces and cleaned.

It is true the generator is somewhat heavy, which is a disadvantage for road locomotion. At first sight the thickness of the tubes appears somewhat excessive, and one would be tempted to reduce it. This, however, would be a serious error, as the total weight of the metal of the boiler is one of the essential conditions of its good working.

If thin tubes were employed the pressure would fall considerably each time water was injected, so that the generator would work very irregularly.

The very high temperature of the steam is also a slight disadvantage from the point of view of the life of the motor This high temperature, which, however, has certain advantages

as we have pointed out, unfortunately vaporises the lubricants and causes a slight smell, which cannot easily be avoided, and also causes the rubbing surfaces of the motor to wear more rapidly than they would if the saturated steam of ordinary boilers were used instead.

A large number of self-propelled trams, built upon the Serpollet system, are already in use in Paris. We will describe the ordinary type for fifty passengers which has been adopted by the *Compagnie des Tramways de Paris et du département de la Seine.*

Each motor car, or rather self-propelled tram, must be able to haul another car, containing the same number of passengers, on gradients of 1 in 20, and keep the time indicated in the official time table.

The total load of these trains is about :

Motor Car	17,600 lbs.
Car hauled	7,700 ,,
103 passengers, including driver and conductors	17,380 ,,
General	220 ,,
	42,900 lbs.

Minimum radius of curves	49 ft.
Distance between axles	6 ,, 2 in.
Diameter of wheels	2 ,, 7 ,,

Generator.—The arrangement shown on Figs. 26, 27, and 28 has been adopted to obtain a sufficient heating surface without having to make the generator too high.

The bundle of tubes consists of two parts : one a series of horizontal tubes, *A*, heated direct by the fire ; the other a series of vertical tubes, *B*, around which the flames or hot gases of combustion pass on their way to the boiler as they would pass through the tubular boiler of an ordinary locomotive. In order to utilise the heat of the gases as much as possible, the tubes have been arranged in quincunx, as shown on Fig. 26.

The front and sides of the generator are provided with doors for the purpose of cleaning the soot which is deposited on the tubes, of tightening the joints in case of steam leakage,

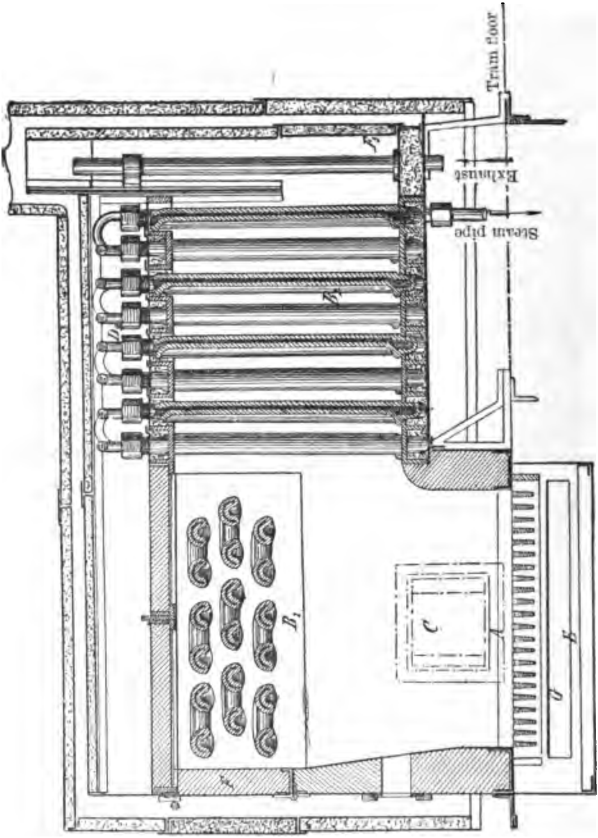


Fig. 26.—Serp Generator. (Longitudinal Section.)

or for stopping the draught of the fire by allowing atmospheric air to cool the tubes.

The dimensions of the generator are as follows :—

Height 3′ 6½″
In plan 5′ 9″ × 2′ 2¾″

The grate area is about 3·01 square feet, and the heating surface is about 43 square feet.

The grate area is therefore large compared with the heating surface (see Chapter III.). This device has been adopted in order to be able to produce more steam, on an emergency, than the boiler is meant to supply in ordinary working.

The generator weighs about 720 lbs., and works at 20 horse-power with a pressure of five atmospheres. If required, it can work for a certain time at fifteen atmospheres, and even over, and can supply 60 horse-power to the motor if the latter has been built in accordance with such a high power.

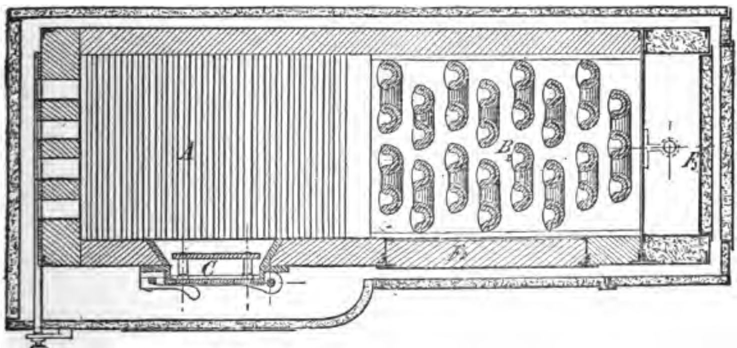


FIG. 27.—Serpollet Generator. (Cross Section.)

As shown on Fig. 29, the engine has two cylinders, which are placed between the wheels, so as to be easily examined.

The main shaft carries three steel toothed wheels, which, by means of strong *Gall* chains, transmit the movement on the one hand to the front axle, and on the other to the rear axle, in the proportion of one revolution to every three revolutions of the engine crank.

The inside diameter of the cylinders is 5·9 inches, and the piston stroke 6·3 inches.

The engine has a reversing lever, and the lubrication is automatic.

In order to protect them from dust and mud the motors are encased in two air-tight metal boxes, which are connected with the fire-box by a pipe, and this arrangement avoids the smell of burnt oil to some extent, as the air required for combustion passes through this pipe so that the oil vapours are drawn into the fire.

A pipe, branched to the exhaust pipe, runs the whole

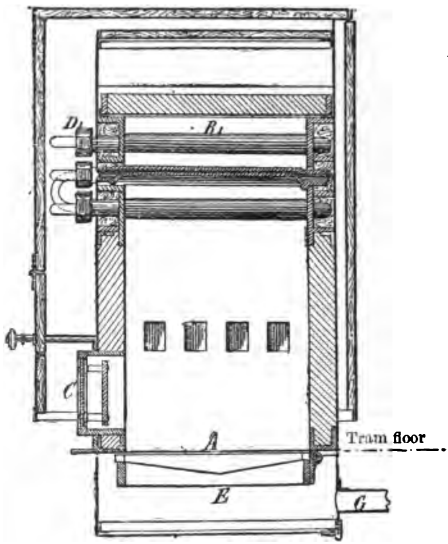


Fig. 28.—Serpollet Generator. (Cross Section.)

length of the car, and is used for heating purposes in winter. In summer it can be closed by a stopcock.

An eccentric is keyed to the front axle, and works the automatic pump, *P*, by means of a rod, *T*, and a lever, *L*.

The hand pump, *P′*, which is used for starting purposes, is worked by a lever, *N*, well within reach of the driver. The pumps *P* and *P′* are cast together, so that the same piping may be used for both, and the mechanism is thereby simplified.

Brakes.—Mr. Serpollet's car has two brakes—the ordinary Lemoine brake employed on omnibuses and a screw brake called a *safety brake*. The first of these brakes is used for stopping the car in ordinary working, the other being only employed whilst descending steep inclines, so as to avoid placing the foot on the pedal which works the brake cord all the time the car is running down the incline. The screw brake can also be used should the ordinary brake fail.

Driving of the Car.—The driver controls four apparatus placed in front of him :

The hand pump,
The regulator,
The reversing lever,
The brake.

A few strokes of the hand pump are sufficient to start working, and from that moment the speed of the car is controlled by the regulator alone.

The car is stopped by means of the pedal brake, and in most cases, when the stops are not long, the handle of the reversing lever need not even be placed at the

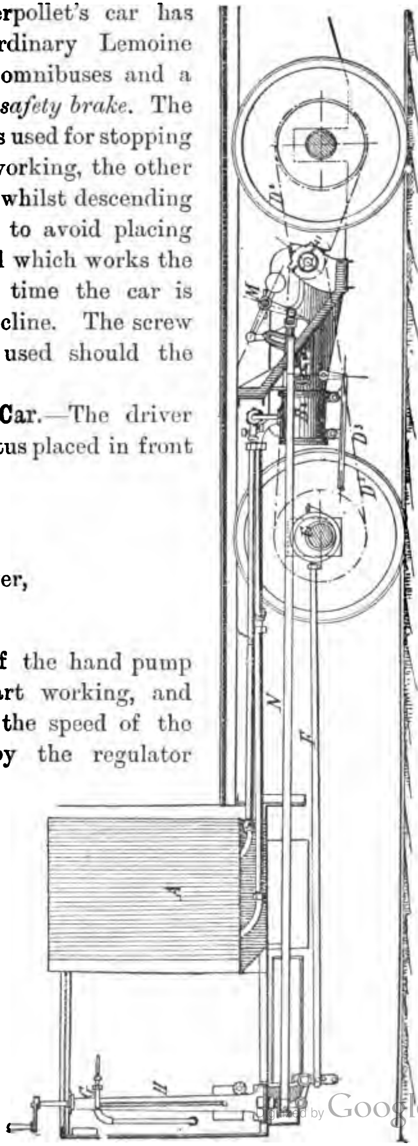


FIG. 29.—Machinery of Serpollet Tramcar.

dead centre. During the stop the steam pressure increases, so that when the driver releases the pedal the car starts of itself.

This easy method of working is very important for road locomotion in Paris, and is much appreciated by the drivers of Serpollet tramways, who in most cases are no other than old tramway employés.

If the stop is long the engine must be brought to its dead centre. The driver fills the fire before starting, and need not attend to it during a six miles run. In fact, the fire is never attended to during a journey: it is only stoked at each terminus.

The cost of working per car-mile can easily be found, as about 6 lbs. of furnace coke are consumed per mile. Taking the cost of coke in France at 16*s*. per ton, the cost per car-mile comes out at about 0·51*d*. Even at double this sum the Serpollet system of traction is still a very inexpensive one.

Of course, all types of cars of all dimensions can be built on this principle. The description of a tramway with a Serpollet motor will suffice to enable the reader to understand all the possible applications of this system.

We will now pass on to a description of Mr. Maurice Le Blant's tractor, which is one of the most successful applications of the Serpollet generator to road locomotion.

THE LE BLANT CAR AND TRACTOR.

Le Blant's is perhaps the best-designed steam car. This engineer did not attempt very light pleasure cars, because he foresaw that petroleum motors were much more applicable to this purpose than steam motors, which could never compete in weight with the former, on account of the considerable storage of water and coal and comparatively heavy boiler required. Again, petroleum motors are certainly cleaner than steam motors. Le Blant saw that the only practical application of steam motors was for heavy cars, omnibuses, and for

vehicles carrying goods between towns and villages where the question of appearance was a secondary one.

In the competition organised by the *Petit Journal* (July 22, 1894) Mr Le Blant's car obtained the third prize, and made a very creditable run from Paris to Rouen.

Here are some figures relating to this car :

The car weighed empty, without tools or brake	5,852 lbs.
Tools and brake	220 „
10 passengers, at 154 lbs. each . . .	1,540 „
Stoker	154 „
Water (132 gallons)	1,320 „
Coal	440 „
Total . . .	9,526 lbs.

During the journey from Paris to Rouen about 10·56 lbs. of coal were used per mile, which is a comparatively high figure, but is due to the bad state of the grate. On a journey of 24 miles the same car does not use over 8·8 lbs. of coal per mile. One generally allows about 28 lbs. of water per mile, so that, with the maximum supply stated above, a run of 47 miles could be effected without renewing the supply of water.

Taking the price of coal at 32*s.* a ton,[1] one gets an expenditure of 2*d.* per mile, or 0·2*d.* per passenger carried.

Mr. Le Blant has not altered his cars, essentially, since 1894, but he has reduced the size of his driving wheels, so as to offer greater strength for the same weight. He employs exceedingly powerful motors, so as to run up the steepest inclines, and to avoid being stopped by bad or sodden roads. As we have already seen, the Serpollet generator is extremely well adapted to this purpose, as the working pressure can be doubled or trebled on an emergency.

Fig. 30 shows one of the latest tractors manufactured by Le Blant, to whom we are indebted for the figures concerning the motor and boiler.

[1] These are French prices.

Boiler.—This generator is of the Serpollet type, but the tubes are arranged differently, and are 7·21 feet long, a size not generally used in this type of generator. The lower tubes, which are subjected to the greatest heat, are round, and are placed crosswise, so that their length is less than that of the upper tubes, which are placed lengthwise. This arrangement has been adopted to prevent the lower tubes from bending, due to expansion under the extreme heat to which they are subjected.

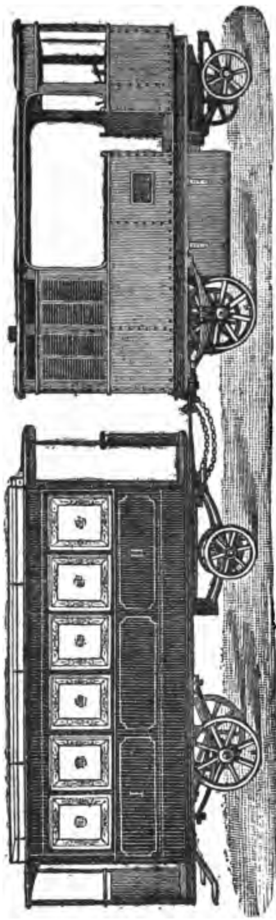


FIG. 30.—The Le Blant Tractor.

Fig. 31 shows a section of these tubes, which have an inner core kept in place by studs. The upper tubes are curved in the form of a U, like those Mr. Serpollet employs in his boilers (see p. 72).

The heating surface is 130 square feet, and the grate area 6·5 square feet. The ratio between the heating surface and the grate area is therefore $\frac{1}{20}$, which is very high, as usually this ratio does not exceed $\frac{1}{30}$ (see Chapter III. p. 39). Mr. Le Blant has increased the grate area in order that the generator may provide a large supply of steam when called upon to do so, which often happens.

The exhaust, which is regulated at will, according to the power required, takes place in the chimney, and serves to increase the draught. The ash pan can be closed.

Water is supplied by injection, and several steam cocks are fitted to the generator. Two feed pumps are provided, and a hand pump for starting. A small donkey-engine with two cylinders works the feed pumps. The return of water to the tank is effected through a valve on the injectors, and is controlled by a lever worked by foot. (See cuts relating to the Serpollet boiler.)

Motor.—The motor has a maximum of 60 horse-power, whereas the boiler just described can only supply steam for 40 horse-power in ordinary working. We have already accounted for this discrepancy. In ordinary working, and on the level, the motor will, perhaps, only work at a third of its normal power; but up a steep gradient the whole of the 60 horse-power that the motor can give may be required, and we know that the generator has a marvellous facility for adapting itself to high pressures for a comparatively short time, and that it can, when called upon, considerably exceed the ordinary supply of steam required for the motor to work at 60 horse-power.

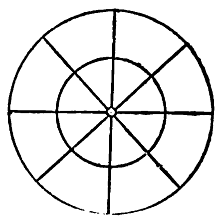


FIG. 31.

The motor has two cylinders, working cranks, set at 90 degrees to one another in order to avoid the dead centre. Each cylinder is 7·87 inches in diameter with an 8·66-inch stroke. The admission of steam takes place by means of balanced slide valves. The link motion is that known as Walchart's system, which does away with the ordinary link and yet enables the engine to work at different degrees of expansion and to reverse easily.

For any further information on the Walchart system we refer the reader to special works on the subject.

The motor gives 60 horse-power with 180 revolutions per

minute at a pressure of admission of 142 lbs. per square inch. In ordinary working only 20 horse-power is required, and the pressure of admission falls to about 15 per cent. The

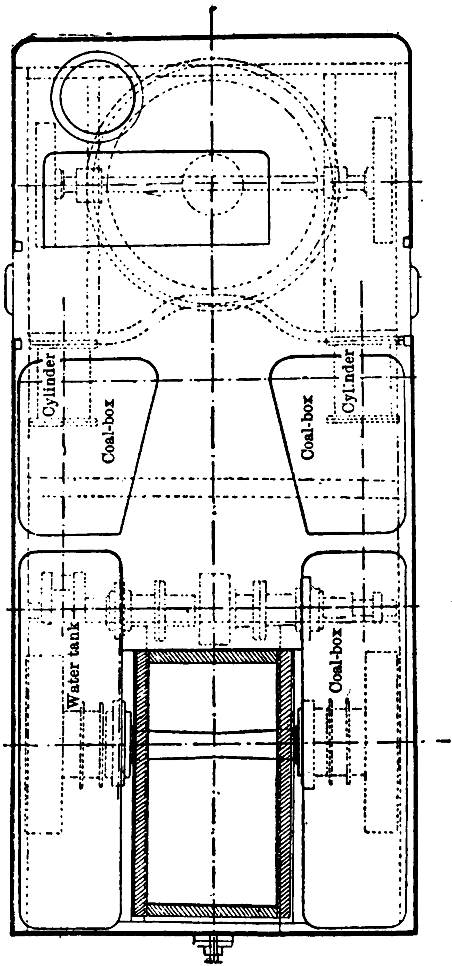


FIG. 32.—The Le Blant Tractor (plan).

parts and the framework of the motor are in cast steel, only the body of the cylinders and piston rings being in cast iron. The total weight of the motor is 1,980 lbs.

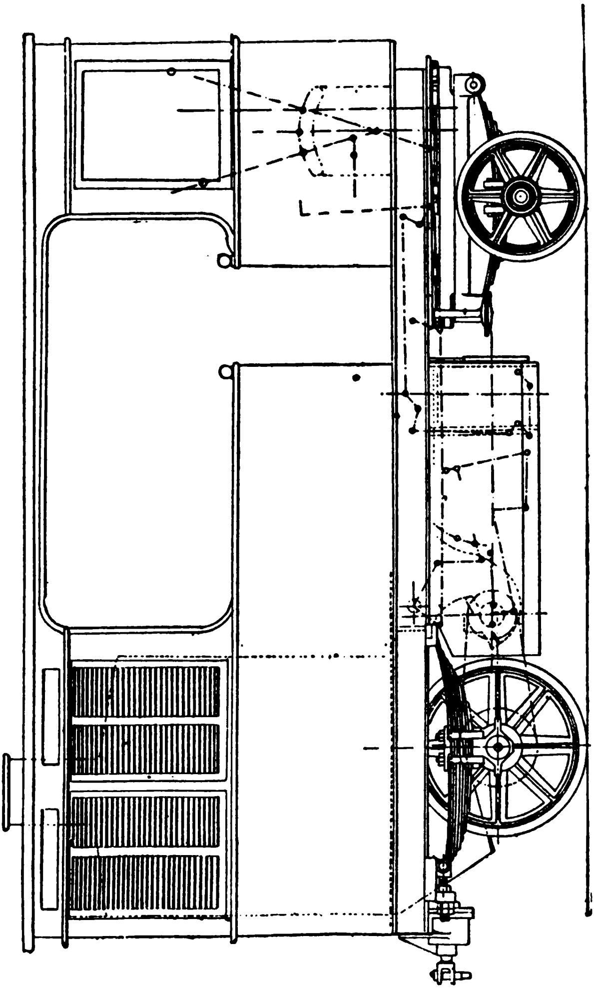


FIG. 33.—The Le Blant Tractor (elevation).

Figs. 32 and 33 show the general arrangement adopted by Mr. Le Blant.

The pitch chains work upon the rear wheels and exert a pull of 4,400 lbs. They can, however, exert a pull of 11,000 lbs. without breaking. The fore-carriage works upon a pivot, and is steered by means of two toothed wheels and an ordinary chain. This arrangement appears to give good results, and enables the car to turn in its own circle. A rigid fore-carriage could also have been used by employing the divided axle system, which we will describe when dealing with other cars using this system, but we think that, although applicable to small cars, it would be dangerous to adapt it to heavy tractors or hauling cars.

The following are some figures concerning Mr. Le Blant's 60-horse-power cars :—

	lbs.	
Weight empty	14,300	Tractor or hauling car.
Maximum supply of water	1,430	
" " coal	550	
Weight empty	3,740	Car hauled.
Maximum supply of water	1,320	
Luggage	1,320	
20 passengers	3,300	
Total	25,960 lbs.	

With the above figures and with the aid of the formulæ set out in Chapter I. we can easily arrive at an estimate of the horse-power absorbed in propelling such a car and tractor at any required speed.

Mr. Le Blant's auto-car for 20 passengers weighs about 15,400 lbs. when empty, and requires about 9 gallons of water per mile.

We consider the above as among the best steam cars now being manufactured. Their workmanship is good, and they will be found useful to those who are bold enough to employ mechanical traction instead of animal traction. Like the Serpollet cars, they have enormous advantages over other steam

cars, as they can run in towns without having to conform to the severe regulations which control the working of ordinary steam boilers. This is almost a question of life and death.

THE DE DION & BOUTON STEAM TRACTORS.

Messrs. de Dion & Bouton have applied their boiler not to auto-cars properly so called, but to tractors or cars for hauling another vehicle. Their apparatus is really *a horse*—an iron and steel horse—strong, never tiring, but very ugly to look at when coupled to a light and handsome car. It is a hippopotamus drawing a canoe behind it, and in our opinion nothing is so ugly as to see this steam monster puffing and blowing and hauling a coupé or a landau.

We are not criticising the tractor itself, because it is an extremely useful one, but we are criticising its application to pleasure locomotion. It is excellent for the purposes of transport between two places, for the carriage of heavy goods, and for hauling heavy vans, although it cannot, like Mr. Le Blant's tractor, give sudden pulls for the purpose of starting again in difficult places on the road.

De Dion & Bouton Generator.—Messrs. de Dion & Bouton's boiler is one of the main points of their motor, and, although small in size, is capable of high steaming power.

Fig. 34 shows a section of this generator. Fuel is passed through the tube *G*, closed by a cap, *M*, and falls upon the grate, *L*, heating the water contained in the annular spaces between the plates *A*, *B*, *G*, and *D*. These two reservoirs are connected by a series of tubes, *C*, so arranged as to impede the gases and absorb their heat. A diaphragm, *K*, between *G D*, forces the steam to pass through the upper bundle of tubes, thus drying it thoroughly. The steam is superheated before passing into the cylinders by passing the steam pipe through the fire box casing, so as to avoid condensation on the walls of the motor, which, as we have already seen, would mean considerable loss of heat.

The gases of combustion are carried to the rear of the car by means of the chimney, *H H'*.

Owing to the arrangement adopted a fairly strong current of water passes in the tubes *C*, which facilitates steaming and prevents the tubes from getting foul too rapidly. This circulation of water is caused by the difference of temperature in the lower and upper tubes, and it will easily be seen that in *G D* the current has an upward, and in *A B* a downward, direction.

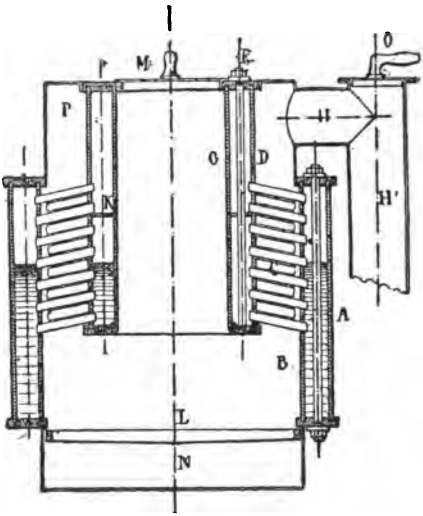


FIG. 34.—The De Dion and Bouton Boiler.

The following figures[1] will show at once the advantages of these boilers :

Heating surface	22·76 square feet
Grate area	1·86 square feet
Weight, empty	528 lbs.

This boiler is sufficient for an 18-horse-power motor, which is remarkable for a boiler only weighing 528 lbs.

It steams about 6 lbs. of water per lb. of coke, and its efficiency is therefore high, and from this point of view slightly better than that of the Serpollet generators.

Motor.—This motor, shown on Figs. 35 and 36, is compound. The large cylinder has a diameter of 7·08 inches, with a stroke of 5·11 inches, whilst the diameter of the small cylinder

[1] *Locomotion automobile.*

is 4·72 inches. The volumes of the two cylinders have been calculated so as to obtain the same amount of work from each, which is the system adopted on all engines of this type.

Steam is admitted into the small cylinder during eight-tenths of the stroke, the engine working at its normal speed

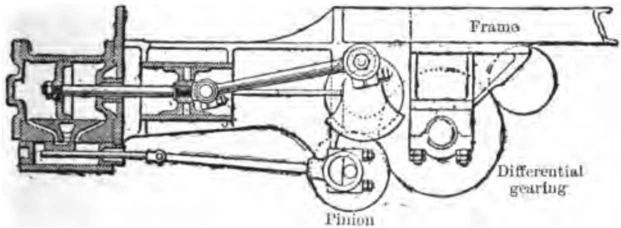


Fig. 35.—De Dion Motor (elevation).

of 330 revolutions per minute. This enables the tractor to travel at a speed of $12\frac{1}{2}$ miles an hour with 18 horse-power.

For starting and for running up gradients high-pressure steam is let into the large cylinders by means of a cock.

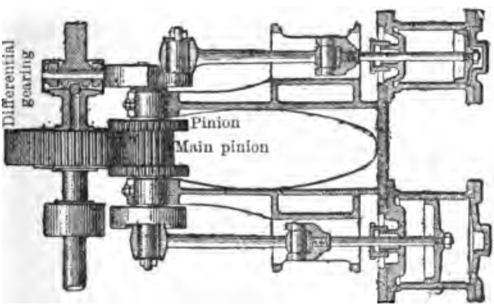


Fig. 36.—De Dion Motor (plan).

A pinion on the main shaft works on a differential gearing, which enables the speed of the wheels to be varied. To avoid using pitch chains, Messrs. de Dion & Bouton have adopted a Cardan joint, which connects the driving shaft to the shafts working the driving wheels. The journal carrying the wheel

is hollow, and the end of the shaft worked by the last Cardan joint passes through the hollow of the journal to the outside of the wheel boss.

The following is a brief description of the Cardan joint: Two shafts, *A* and *B* (Fig. 37), are joined together by a collar. Each shaft has two journals, *a* and *b*, *c* and *d*, fitting, at right angles to one another, into the collar. The lubricant passes through a groove, and lubrication improves with the speed of the shaft, as the oil is driven round the journals by centrifugal force.

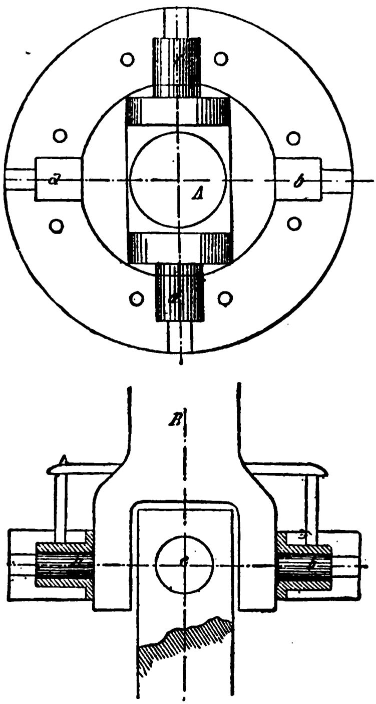


Fig. 37.—Cardan Joint.

By arranging two of these joints between two shafts one of the latter can shift freely with regard to the other. The discs of these joints describe a circle equal to the relative displacement of one disc to another. By this arrangement the tractor can move independently of the motor without using chains, which are often a source of trouble.

In order to show the high tractive power of Messrs. de Dion & Bouton's cars we may say that pattern No. 1 weighs 4,400 lbs., and can haul a load of 2,640 lbs. at 12½ miles an hour. The fuel consumption comes out at about 1·6*d.* per mile.

Pattern No. 2 weighs 8,800 lbs., and hauls 22,000 lbs. at a speed of 4·8 miles an hour. These powerful tractors may render good service in hauling heavy loads, such as ammunition waggons, vans, &c., which at present require a large number of horses difficult to manage. How much simpler it would be to use a tractor similar to the above! Not only would it be more simple, but also much more economical, and there would be advantages in adopting it in all respects, but unfortunately routine and force of habit prevent our adopting this new method in one day.

We cannot, however, recommend this tractor for pleasure auto-cars, for reasons already given.

THE BOLLÉE CAR.

It was only in 1875 that Mr. Amédée Bollée, of Mans, took up seriously the study of road locomotion. We certainly owe to him the first really practical steam cars, and the place which his steam omnibus, *La Nouvelle*, built in 1880, took in the Paris-Bordeaux race shows to what degree of perfection on the subject this engineer had already arrived. In fact, Mr. Bollée's son came ninth in the race with this ancient car, notwithstanding the unfortunate accident which had almost placed *La Nouvelle* 'hors de combat' at the beginning of the race. Although ninth, Mr. Bollée's car was the first to come in of the steam cars taking part in the race.

Bollée Steering Gear.—Mr. Bollée first attempted to improve the steering of four-wheeled cars. He noticed that a movable fore-carriage swinging round a pin was not at all a suitable arrangement, because if the wheels were turned at an angle of 90 degrees around the pin the car had no more stability than a three-wheeled car.

To avoid this Mr. Bollée adopted a *fore-carriage with two pivots.*

This arrangement consists in having a *divided axle*, the

centre part being rigidly attached to the car frame and the two steering wheels, *m*, being made to turn on two separate pivots by means of two cams, *e* and *e'* (Fig. 38).

These two cams work the two pivots, *p* and *p'*, by means of chains and two small toothed wheels keyed to *p* and *p'*. The cams and toothed wheels are so designed as to cause different displacement to the two wheels when steered: thus, if by means of the steering bar the wheels are turned in the direction shown on the figure, the wheel *F* will describe a larger angle round its pivot than the wheel *F'*, so that both wheels tend to turn the vehicle round the same centre, *O*. If

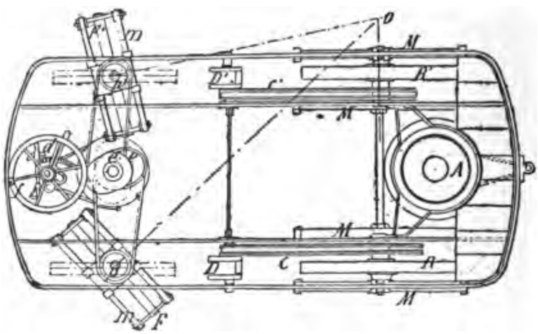


FIG. 38.—The Bollée Steering Gear.

this were not the case one of these wheels would be skidded, which would have a detrimental effect not only on the pivots, but on the whole car.

The car has, therefore, much more stability than one in which the fore-carriage works round a pin, as it always bears upon four supports.

Boiler.—Mr. Bollée uses Field boilers on his cars similar to those employed for fire pumps. Figs. 39 and 40 show this boiler.

E is the boiler proper, inside which is the firebox, *F*, and the grate, *G*. The chimney, *C*, is inside the cylindrical casing.

The tubes *t* are arranged, as shown on the figure, to impede the passage of the gases. The outer tube *t* is riveted to the boiler shell, and contains a small tube *t'* held in the centre of *t* by the collar *m*, as shown on Fig. 39. The lower part of these tubes being most exposed to the heat, the water will circulate rapidly in the direction shown by the arrows, so that the simultaneous heating of the whole of the contents of the boiler will be much accelerated, the heating surface will be utilised to its greatest extent, consequently giving the boiler a high steaming efficiency.

This system steams 20·5 lbs. of water per square foot of heating surface per hour. Getting up steam is so rapid that these boilers have been employed for fire pumps, and the wate

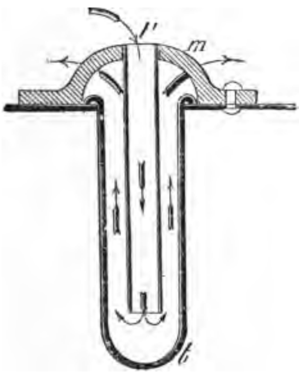


Fig. 39.—The Field Tube.

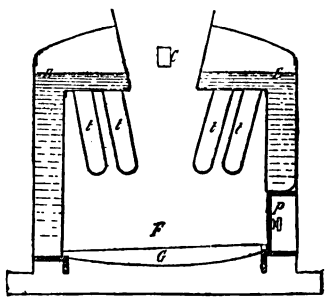


Fig. 40.—The Field Boiler.

circulates so rapidly in the tubes that there is no incrustation in the boiler.

The outside diameter of the Field boiler used in *La Nouvelle* is 30·31 inches, and it contains 118 tubes. Steam is got up in twenty minutes; the boiler is registered at 142 lbs., and supplies superheated steam at 300° Cent.

Motor.—The motor consists of two cylinders, set at 45 degrees to one another, fitted with a balanced rotary distributor for expansion and reversing. The diameter of this cylinder is

5·9 inches, and the stroke 6·29 inches. The motor has 15 horse-power ordinary working, but can give as much as 30 horse-power at full pressure.

The total weight in working order of this steam omnibus is about 10,120 lbs., including stoker, driver, and eight passengers. It can easily travel at 17 miles an hour, and sometimes even at 27 miles an hour on the level.

Mr. Bollée has built a large number of other cars, which are the same in principle, and only differ in shape and detail. These cars are interesting, not for any new ideas in their machinery, but for their excellent and practical workmanship. In a word, they are the work of an old mechanic who knows his business thoroughly, and attempts nothing which he cannot accomplish. The result obtained in the Paris-Bordeaux race with a fifteen-year-old car is alone sufficient testimony of its value.

We hear that Mr. Bollée has just built a petroleum tricycle, which is well spoken of.

THE FILTZ ROTARY STEAM MOTOR.

The Decauville Company has lately been trying a new rotary motor invented by Mr. Filtz. This apparatus has been modified to such an extent that we hardly recognised the original principle on which it was built, six years ago, except that the new motor is still rotary.

Figs. 41 and 42 show a longitudinal and cross section of this apparatus. It consists of a stationary cylinder, c, working a piston, P, shaped thus—. The ends of the cylinder are screw-shaped, one with a right-hand thread and the other with a left-hand thread. This is shown in dotted lines on Fig. 41. The pins o and o' slide in a slot in the piston at the two extremities of a common diameter of the piston. We see at once from the form of the cylinder cover that the piston will impart a reciprocating movement to the pins. At one moment the pin o, for instance, will be pushed home to the

left, and the piston will bear against the screw-shaped end of the right-hand cover of the cylinder.

The above process is reversed when the piston has made a half-turn.

The steam port a' is placed just beyond the point of contact between piston and cylinder end.

The exhaust port e' is just before this point, and has a longitudinal shape.

Let us examine what takes place, and assume the piston

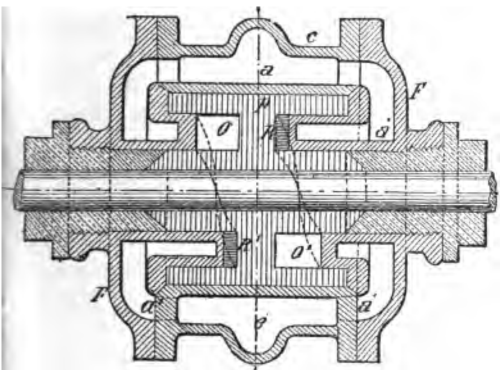


FIG. 41.—Filtz Motor (longitudinal section).

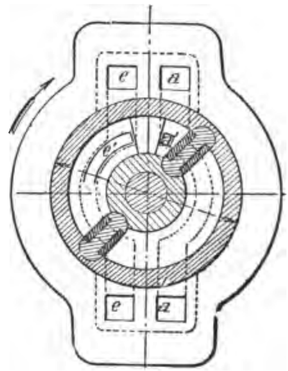


FIG. 42.—Filtz Motor (cross section).

to be in the position shown in Fig. 42. The space to the right of the centre line of the piston is divided into three chambers. Steam is admitted into the first compartment, in the second it is expanded, and in the third it communicates with the exhaust port e'. It will easily be seen that steam will be admitted at a' till the pin o' arrives at a', when the pin o will be in the lower part of the cylinder. Steam is therefore admitted during a half-revolution. From this moment steam expands in the second compartment owing to the larger area of the pin o' compared with that of o, and will continue expanding till both these areas are equal, which will take place when the two

pins occupy a horizontal position. When the motor passes this point steam will communicate with e', as in the third compartment.

A similar process takes place on the other face of the piston.

Such is the very simple method of working of the Filtz motor, which is a very practical apparatus.

The inventor has also endeavoured to make it work economically by converting it into a compound motor.

This was easy to accomplish by simply coupling together two similar engines of different sizes, and making the exhaust port of the small cylinder communicate with the admission port of the large cylinder.

In applying this motor for haulage purposes it was necessary, however, to have a reversing arrangement. The motor has consequently been provided with a slide valve which directs the steam into another set of passages so arranged as to cause the motor to revolve in an opposite direction. We should point out also that the motor will start in any position except that in which the pin is exactly opposite the steam port.

The following Table [1] gives some details concerning the Filtz motor:—

SINGLE-CYLINDER MOTOR. STEAM PRESSURE, 85 lbs.

H.P.	Diameter of cylinder	Number of revolutions	Weight
	ins.		lbs.
3	3·70	1,200	132
5	6·69	500	220
10	7·87	400	330
COMPOUND MOTOR. STEAM PRESSURE, 85 lbs.			
10	7·87— 9·84	400	572
20	9·84—16·53	350	1,540
49	13·78—23·62	300	2,640

The single-cylinder motor requires from 48 to 53 lbs. of steam per brake-horse-power per hour, and the 40-horse-power

[1] Extract from the *Revue Industrielle.*

compound engine about 30 lbs., the latter corresponding to 20 lbs. of steam when working with condensation.

These are more than satisfactory results for a motor used for road locomotion, and if it could be worked by petroleum we should be disposed to think very highly of its possibilities.

THE ROWAN STEAM TRAMCARS.

The Rowan steam tramcar is simply the combination of a boiler with an ordinary steam engine, so arranged that little, if any, smoke or steam is visible.

As all the parts have been designed with such care, we will give a complete description of this system, in order to show how an ordinary steam-engine can be converted into an exceedingly economical and comfortable self-propelled car.

We will first give an account of the conditions of working of the Tours-Vouvray line, on which this tramcar is employed, and then follow it up with a description of the motor and machinery taken from an article by Mr. Saintive, published in the *Revue Technique* of September 9, 1894.

The Tours-Vouvray line is 6 miles long, nearly all on the level, and with a single line of rails. There are, however, some gradients of 1·2, 1·3, and 1·8 in 100, which are 410, 302, and 190 feet long respectively.

The cars stop for passengers at any point along the road, the whole distance being covered in 45 minutes, which is equivalent to 9 miles per hour, not counting the stops.

Each motor-car seats 50 passengers, and hauls another car with roof seats (shown on Fig. 43) carrying 70 passengers.

A condenser, described farther on, is placed on the top of the motor-car. The carriage body has three compartments, parcels being carried in the fore compartment; it is mounted on two bogeys—a front bogey, which carries the motor, and a rear bogey.

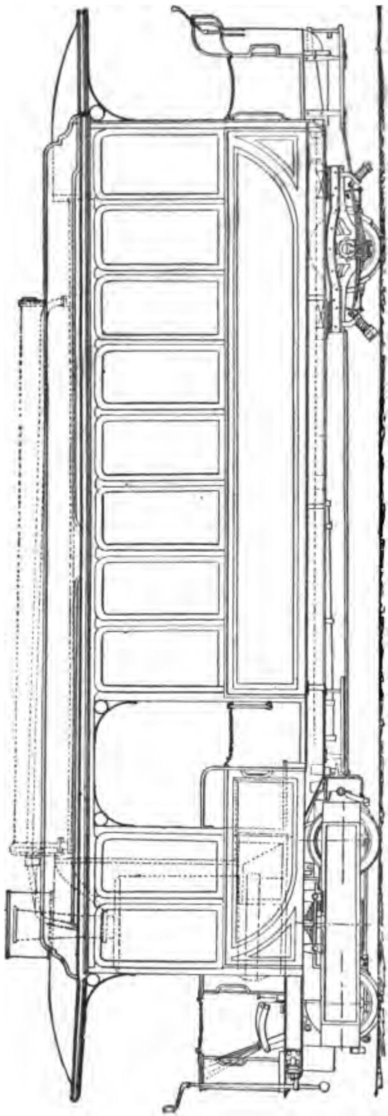


FIG. 43.—The Rowan Tramcar.

The carriage body is carried on bogeys by means of bearing springs with slide blocks, which work in two circular guides on the framework of the motor.

This arrangement enables the car to go round 65-foot curves without any difficulty.

The rear bogey has a single axle, fixed to a frame as wide as the car. This frame is connected to the car body by a centre pin, which thus allows the axle to turn independently of the car body.

Motor.—As we have already said, the motor is placed quite in front of the car, and its weight, together with part of the weight of the car itself and passengers, is sufficient to give the necessary adhesion, even on gradients of 6 in 100.

The boiler (shown on Figs. 44 and 45) is vertical, and is fixed to the frame by a ring bolted to the under-frame plate in front of the motor, and by a lower ring bolted to the sole-bars of the under-frame.

The outer shell of the boiler consists of two cylindrical plates bolted together. It can be taken off, thus disclosing the inner shell, which is also cylindrical round the fire-box, but rectangular in section at its upper part. The prism thus formed has inclined tubes passing through it which impede the passage of the gases and increase the heating surface. The inclination of the tubes insures a good circulation of water, and consequent uniform heating and prevention of too rapid incrustation.

The heating surface is 95 square feet, and the grate area is 17·43 square feet. The sides of the fire-box are 0·53 inch thick, and the shell is 0·49 inch thick. The indicated boiler pressure is 200 lbs.

Coke is burnt; a thick layer may be built up before starting, and it requires no attention on the road. If coal were used this would not be possible, because it impedes the passage of air to a greater extent.

The fire is raked at Vouvray, after a twelve-miles run.

Water is supplied to the boiler by a pump, which takes its supply from a tank behind the motor. This tank is connected with small reservoirs on the car, which collect the water of condensation. A Kœrting injector is used for injecting water during stops.

Machinery.—Outside horizontal cylinders are used, and are placed on the boiler platform: they are 6·53 inches in diameter with 13·38 inches stroke. The wheels are 24·41 inches in diameter, and the maximum pull exerted is 4,653 lbs.

The piston movement is transmitted to the connecting rod by a lever so arranged as to increase the power of the motor in the proportion of 3 to 2. This, however, entails some com-

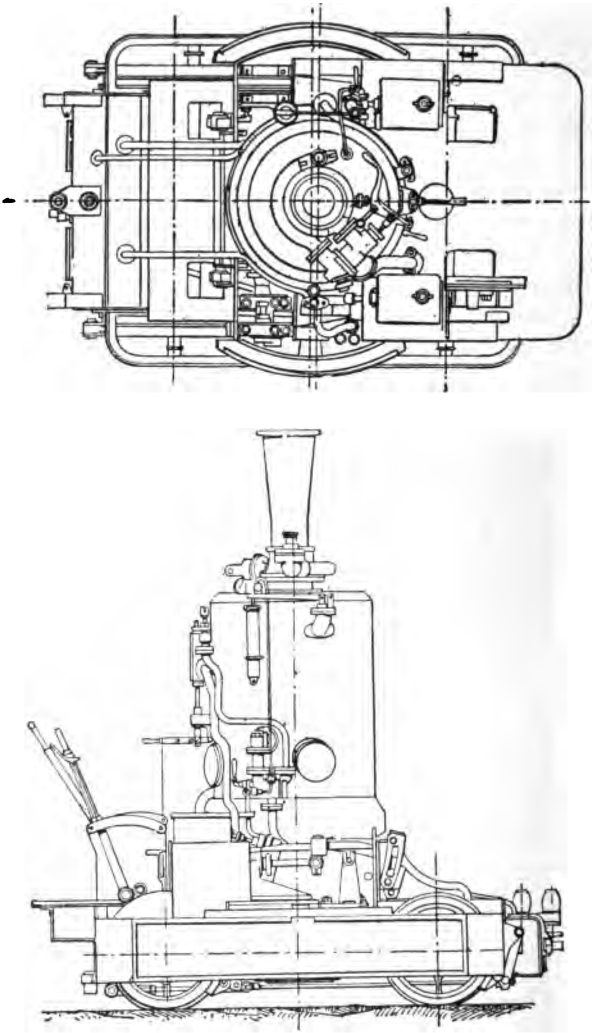


Fig. 44.—The Rowan Boiler.

plication in the parts, and it has a further drawback that an accident to any part of the mechanism stops the engine completely. Such accidents, however, are extremely rare.

The working parts are easily lubricated and inspected on the road, the driver being able to do so without getting off the car.

This is a decided advantage over boxed-in tramway motors, where the driver cannot see that the parts are heating or becoming loose. Reversing is done by means of a lever placed at the right of the driver and well within his reach. The regulator is placed at his left. This arrangement enables them to be easily worked.

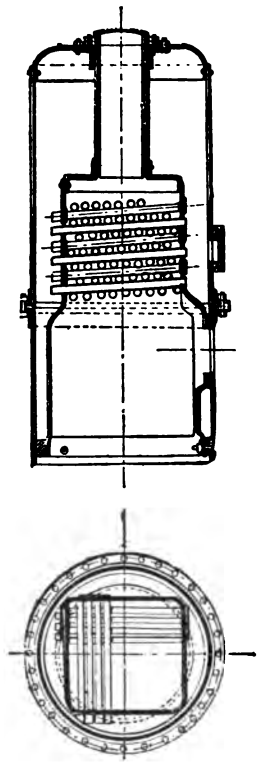


Fig. 45.—Section of Rowan Boiler.

Once the car is started the driver brings the reversing lever to the third notch in the quadrant —corresponding to an admission of steam of about 30 per cent.—and he leaves it in that notch, whatever speed he may require: the pull will depend upon the amount of steam admitted by the regulator. Working at 30 per cent. steam admission is very economical, as there is no wire-drawing of the steam on entering the cylinders; and, on the other hand, as the regulator is not generally full open, the pressure of steam is lowered as it comes from the boiler, which has the effect of revaporising the small amount of water it contains, and of allowing it to arrive perfectly dry, and even slightly superheated, in the cylinders.

The fuel being well burnt, the motor is an extremely economical one. The boiler is fed with pure hot water, and consequently is always in a good condition; in fact, no leaks have yet been found either in the fire-box or in the tubes on any of the four engines now being worked on the line of Tours-Vouvray.

Washing the boilers can be dispensed with, which is an economy of time and labour. They need only be emptied every ten days, and the upper shell has only to be taken oft about once a year. The inner shell being then exposed, it can be cleaned with the greatest ease. The deposits can be easily scraped off, and when the operation is concluded the boiler plates and the interior of the tubes are tarred, which thus prevents the scale from sticking too hard to the sides.

The steam can leave the cylinders through an exhaust pipe placed at the base of the chimney, or into an air condenser fixed to the car, the latter arrangement being most generally adopted.

The condenser, which has about 1,714 square feet of cooling surface, is made of very thin corrugated copper sheets, soldered in couples. The cavities thus formed connect at one end to a collector which receives the exhaust steam from the engine, and at the other end to another collector which has inclined pipes leading to tanks fixed under the car platform.

When well attended to this motor shows neither smoke nor steam, and is therefore well adapted for street and town traffic.

Three auto-cars and one reserve motor are used on the Tours-Vouvray tramway line.

In summer two cars are used on week days, and all three on Sundays.

In winter, however, as departures only take place every two hours, one auto car is sufficient on week days and two on Sundays.

The engines are repaired in rotation, so that by the spring

they are in perfect condition and ready to cope with the heavier traffic.

Three drivers are employed—one for each engine. In summer each car is worked during two consecutive days—sixty miles on the first day and eighty-four on the second—and is put into the repairing shed on the third day for careful examination by the driver, who tightens up any parts that are loose, sees to the piston and valve packings, lubricates the valves and cocks, and regulates the brake-blocks, &c. At the same time a man in the depôt cleans the tubes by means of a rod, so as to remove the soot and cinders that have been drawn into them by the draught. This operation requires to be done exceedingly carefully, and takes an hour at least. The attendant then cleans the machinery and the body of the car.

The total distance travelled per day by the cars is 144 miles on week days and 204 miles on Sundays, which gives an average for each car of from 1,500 to 1,560 miles per month.

When required, the motors can be run for a longer period than two consecutive days; thus, on the Auteuil-Boulogne line, they run from ten to twelve days consecutively, averaging 720 to 900 miles—which is equivalent to a railway locomotive. It is, however, better to examine them in the shed after running from 360 to 480 miles.

The average fuel consumption for Tours-Vouvray motor-cars, hauling a car with 70 passengers (making a total of 120 passengers), is 11 lbs. of coke per mile, including lighting. When the engines are well looked after the fuel consumption can be reduced to 10·31 lbs., and that of the oil to 0·11 lb.

The staff at the depôt consists of only two shunters and a fitter. The plant consists of:

1 8-horse-power stationary engine, supplied by the boiler of the reserve motor.

1 lathe for turning the tyres.

1 screw-cutting lathe.
1 forge.
1 drilling machine.
2 vices.

During summer the fitter prepares spare parts, such as bearings, piston rings, &c., which he may require, these parts being bought in the rough at iron or foundry works in Tours.

From November 1 the engines go into the repairing shed in turn, pistons are examined, and piston rings renewed if required, and trunnions which have too much play are also renewed. Complete renewal of parts is generally only required at the end of every two years.

Slide valves are also renewed at the end of this period.

The rod and axle bearings are provided with an anti-friction white metal made up of the following parts :

Tin	82 parts
Antimony	12 „
Red copper	6 „

The water tanks are examined yearly, and the condenser is cleaned and repaired every other year.

The wheel tyres are only turned after having travelled 4,800 miles. They are again turned after 3,600 miles, and are rejected after they have gone another 4,800 miles. They have, therefore, an average mileage of 13,200 miles, but some travel 14,400 and 15,000 miles. A small apparatus has been designed for watering the rails and the road on the Tours-Vouvray line. This arrangement diminishes the wear and tear of the tyres and driving gear, and protects the passengers from the dust.

It is estimated that this device increases the life of the tyres and machinery of the engine by 25 to 30 per cent.[1]

[1] *Revue Technique.*

STEAM MOTORS WITHOUT FIRE-BOX OR WITH HOT WATER.

A hot-water engine was first tried in 1872 by Dr. Lamm, of New Orleans.

Mr. Francq bought the patent rights and improved the system so as to make it practical and economical.

The main object of this system is to do away with the locomotive fire-box, and this is accomplished by utilising the heat capacity of water, which latter is heated to a degree sufficient to obtain the steam necessary for working the engine. The way in which this is carried out in practice is to pass a jet of steam, at high pressure, taken from a generator at a depôt, into a water tank on the engine; as the steam mixes with the water the latter takes up the heat.

In order to raise the water to the necessary temperature two cocks are opened—one on the steam pipe, the other on the steam reservoir. The high-pressure steam is then forced into the latter, and, by means of small orifices specially arranged in the inner pipe, it sets up a circulation of water sufficient to distribute the heat uniformly.

When the pressures in the boiler and reservoir are equal the cocks are closed, and the locomotive is then ready to start. The heat contained in the water causes the latter to boil as soon as the free space in the reservoir is connected with the engine cylinders.

The motor can then do work on the pistons equivalent, between certain practical limits, to the heat contained in the water. These limits may vary to any extent; in other words, the initial temperature of the water can be raised as much as possible, whilst the final temperature can be made as low as possible.

In practice, the initial temperature may attain 200° C., corresponding to an effective pressure of 213 lbs., and the final temperature may be fixed at the minimum pressure required

by the motor for starting on a gradient ; and, as the latter is only a question of leverage, and depends upon the mechanism, a temperature of 133° Cent., corresponding to an effective pressure of 28·4 lbs. per square inch, will suffice.

Under these conditions low-pressure steam with great expansion may be used so as to obtain maximum efficiency.

A steam expander, fitted between the reservoir containing superheated water and a smaller reservoir which supplies steam at constant pressure to the pistons, enables the driver to overcome any increased resistance on the road due to gradients or other causes ; he obtains a greater pressure of steam on the pistons by means of this steam expander.

Fig. 46 represents a longitudinal section, taken through the axis of the tank, of a locomotive without fire-box.

Fig. 47 is a cross section through the axis of the condenser.

The locomotive consists of a large steel plate reservoir *A*, with a dome *A′* and driving gear similar to that on ordinary locomotives. There are two cylinders *B*, working by connecting rods *C* a crank axle *D*, which drives the two driving wheels *E*. The latter are coupled by two outside rods *C′* with two other wheels *E′* on a straight axle *D′*.

The driving gear is placed between two sole-bars *F*. The framework is covered by a plate *F″*.

Engines are now built with outside cylinders, which simplifies construction and enables the driver to examine the working parts.

The reservoir *A* can hold a large supply of water, which is put in cold and then raised to a very high temperature before the engine starts, by means, as we have already said, of a stationary boiler which steams at a pressure of 213 lbs., and has consequently a temperature of 200° Cent.

We see at once that when a sufficient quantity of steam from the generator is passed into the reservoir *A* the temperature and pressure of the water in *A* and the pressure of the

steam in the dome A' and in the free space of the reservoir must all be in equilibrium.

Assuming that no heat is lost through the walls of the

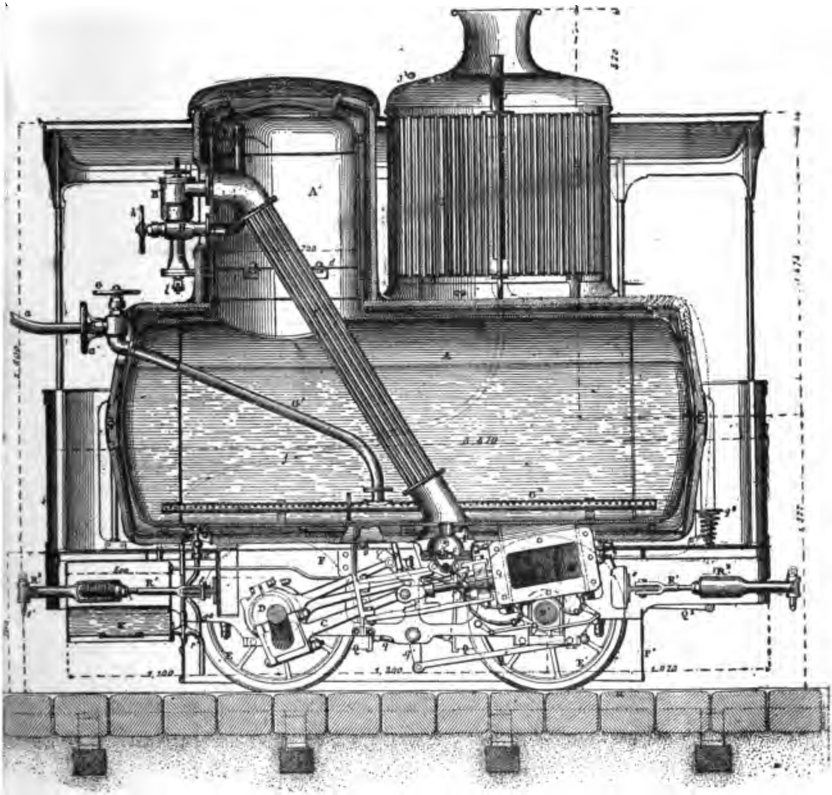


FIG. 46.—The Francq Locomotive.

apparatus, no alteration in the existing state of things will take place so long as steam is not taken away—in other words, so long as the water in the reservoir, which is always ready to be converted into steam as soon as the pressure upon it

is reduced, remains at a temperature of 200° Cent. for instance.

The tube *b* (Fig. 47) is placed inside the dome for conveying

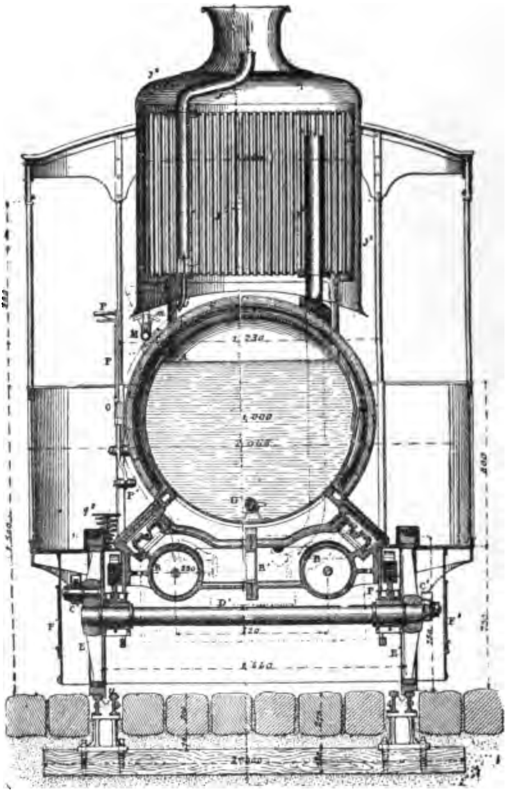


FIG. 47.—The Francq Locomotive (cross section).

the steam into the cylinders. The upper end of this tube, placed as high as possible, has longitudinal slots through which the steam can pass. It is bent horizontally and connected outside with the *steam expander*, which consists of a valve *H*

and the expander proper, which only allows steam to pass into the cylinders after attaining the required pressure.

The valve motion is the same as in other engines, with the exception that the exhaust is not utilised for raising a draught, which is not needed, as there is no fire-box. In order that the exhaust shall show no steam and shall make no noise, an *air condenser*, consisting of a closed cylinder J containing a large number of tubes J' open at both ends to allow the air to pass freely through them, has been adopted.

The steam from the cylinder passes into the box B', common to both cylinders, and then through a pipe B^2 (Fig. 47), which is bent round the reservoir and passes into the condenser.

The exhaust steam can therefore fill the space round the tubes J', and then condense on coming into contact with them, the water of condensation thus formed being carried off by a small pipe leading to a tank K placed under the platform. If, however, condensation is incomplete, the vapour remaining inside the condenser can escape into the atmosphere by a pipe J' which leads to the inside of the cover J^2 of the condenser.

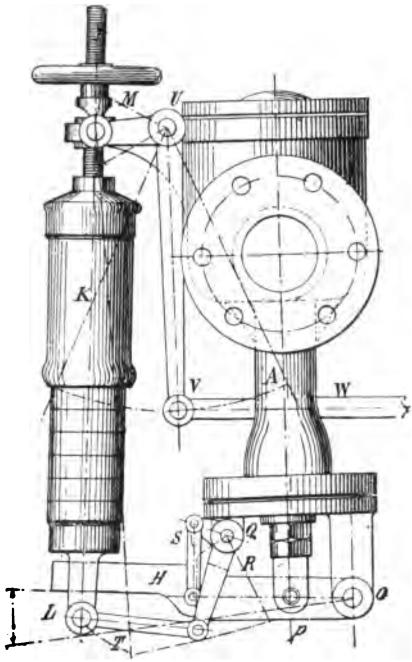


FIG. 48.—Steam Expander.

The steam expander alluded to above is an essential part of the Francq engine. It is shown on Figs. 48 and 49.

Steam arrives from *X* and passes through the valves *B* into the pipe *Y*. The valves only provide a small section for the steam to pass through, so that steam is expanded.

The pressure of steam in *Y* is always from 42 lbs. to 56 lbs. per square inch, whatever it may be in *X*. To obtain this result a piston *D* connected with the valves *B* by means of a spindle *C* is put into communication with the expanded steam.

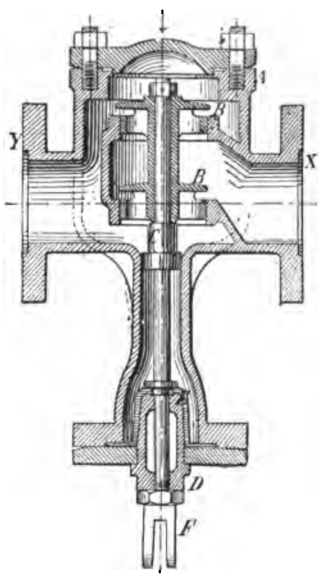


FIG. 49.—Section of Steam Expander.

With steam at 42 lbs. the piston is in equilibrium by means of the levers *H*, *S*, *R*, *T*, and the spring in *K*. When the steam pressure decreases the spring *K* raises the piston *D*, which lifts the valves *B*, and consequently diminishes the amount of expansion. In this way the steam is always maintained at constant pressure in *Y*.

When a higher pressure is required for starting, or on an incline, or for any other reason, the driver can vary the expansion by means of the levers *W*, *U*, *M*, which act on the spring, and so increase the steam pressure in *Y* by raising the valves *B*.

The principle of the Francq locomotive is therefore the storage of water under pressure at a high temperature, which can supply steam when that pressure is diminished. The hot-water engine is based on the principle of stored power, similarly to the electric and compressed air cars which we shall

have to deal with. In short, the hot-water reservoir is nothing else than an accumulator of heat used to convert this water into steam, which acts upon the piston and transforms the stored energy into actual work on the shaft.

There are losses with this accumulator as with others due to radiation and to the expansion of steam which takes place without corresponding useful work. In fact, the steam expenditure in the stationary boilers required for re-heating the water in the hot-water tanks amounts to about 55 lbs. per horse-power per hour, involving a consumption of 7·7 lbs. of fuel.

The consumption of an ordinary locomotive would only be about one-half of the above. This system is therefore not an economical one compared with ordinary steam engines, but when compared with other systems of traction with electric or pneumatic accumulators we find that it is at least as good, if not better.

CHAPTER V

COMPRESSED AIR AUTO-CARS

THE POPP-CONTI TRAMWAY.

This system of mechanical traction has been adopted for the towns of St.-Quentin, Angoulême, Lyons, &c., where the lines have many gradients, and thus allows us to gauge the value of this method of compressed air traction. The trains consist of three cars at the most, and their total length does not exceed 99 feet. The average speed in the towns is about 7½ miles an hour, and in the open country about 15, and even 18, miles.

Messrs. Popp-Conti's system differs from Mr. Mékarski's, already briefly alluded to, as much lower pressures are employed, which give a better efficiency, as the air does not require to be expanded so much before passing into the motor as when very high pressures are adopted. The weight of the air reservoir on the car is also less for this reason, and consequently the depôt for storing the compressed air need not be so large.

As the power stored is less than with Mékarski's system, it was found necessary to recharge the car every one or two miles along the line. To do this the air has to be conveyed through pipes all along the line, and arrangements made for automatic delivery at the different parts of the line where the tramways stop. This is one of the disadvantages of the Popp-Conti system.

Description of the Car.—The cars have a double set of springs. The truck frame is carried by laminated springs

bearing on the axle boxes just above the axles. The car body then rests upon an upper frame supported by other springs at the ends of the truck frame.

This arrangement gives a very easy motion to the car, and enables the axles to be placed very close together, even on long cars, which is a great advantage for passing round sharp curves.

The two axles are connected together by a coupling rod, but only one of them is worked directly by the compressed air motor by means of two toothed wheels cased in a box filled with oil.

Figs. 50 and 51 show the simplicity and strength of this compressed air motor.

The motor is placed in the centre of the car, so that there is no side motion, as is the case with some steam or compressed air cars.

The motor is compound with variable expansion, and, being made of cast steel, it is consequently exceedingly strong. It can easily be inspected from the inside of the car and taken out for repairs, so that in case of any accident the car can be immediately provided with another motor, and does not require to remain idle until the damaged motor has been repaired.

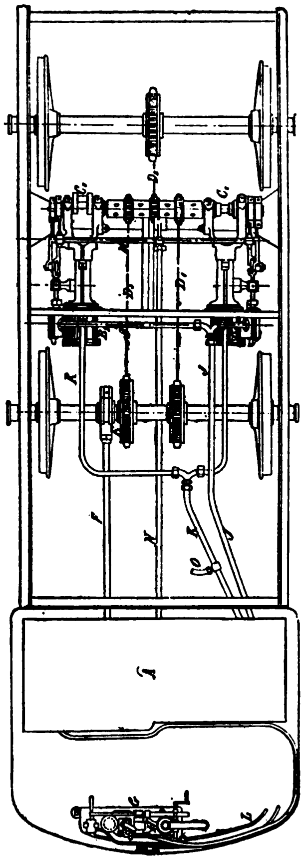


Fig. 50.—Machinery of the Popp-Conti Car.

The compound motor can, if required, work at any point along the road either with double expansion or with direct admission into the two cylinders.

The car is easily driven from either end. The driver has a small wheel and three small cocks in front of him, the latter being used as follows :

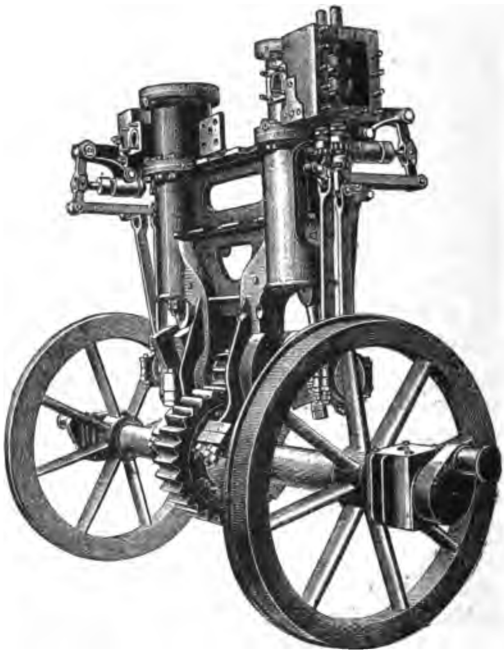


FIG. 51.—Compressed Air Motor.

The first for reversing, the link motion being worked directly by small compressed air pistons instead of through a set of levers. The small cock therefore raises or lowers the links. It will probably have been noticed that this arrangement only enables the links to occupy two extreme positions. There is no disadvantage accruing from this fact, as they are

not required to regulate the expansion. The admission of steam to the small cylinder is regulated by means of a Meyer cut-off, which is worked directly by the wheel in front of the driver. The second small cock works the joint, and we will describe its method of working farther on. The third cock is used for the safety brake, and enables the pressure to be admitted behind the pistons working the brakes.

There only remains now to describe the working of the wheel, which produces different results for every revolution which the driver causes it to make.

The first revolution enables him to graduate the pressure on the brakes; the more the driver turns the wheel round towards the left the more he increases the pressure. By turning the wheel towards the right the pressure of course decreases, so that each position of the wheel corresponds to a different pressure on the brakes. Supposing the wheel to be at the end of its travel towards the left, then the brakes exert maximum pressure. If the driver turns it once to the right the pressure on the brakes will decrease progressively to zero: at that moment the motor will be open to external air. If the driver continues turning the wheel to the right he will cause air to pass into the small cylinder till he has turned the wheel round twice. The engine will then be working in a compound manner, and the driver can regulate the speed of the train by means of the wheel which works the Meyer cut-off.

The wheel can make three revolutions, and the third enables him to treble the power of the motor for any emergency purpose. In fact, if the driver continues turning his wheel towards the right he leaves compound working and begins working directly; that is to say, he opens the exhaust of the small cylinder to the external air, and causes air from the reservoirs to pass directly into the large cylinder, so that at a certain moment both cylinders will be at full pressure. By turning the wheel to the left the above process is reversed; that is to say, on the first turn he goes back to compound

working, on the second turn the motor is open to air, and at the third turn the pressure on the brakes is maximum.

This has the advantage of preventing mistakes on the part of the driver, as when he wishes to work the brakes he is forced to open the motor to air, and *vice versa.*

By means, therefore, of the system we have just described, the various combinations of admission of compressed air into the motor cylinders, starting, regulation of power and speed, stops, and working of the brakes all take place in a definite order by simply turning a wheel within reach of the driver.

The cars are worked from both ends, so that no turntables are required at the termini.

Automatic Air Charger.—Having decided only to employ moderate pressures, it was necessary to devise some arrangement for renewing the supply of air along the road.

This was the great difficulty. There could be no question of having men on the line specially employed for connecting the joints, working the cocks, and then disconnecting the joints after recharging, as is done on tramways with air accumulators at charging stations. These manœuvres would take about three or four minutes, and the consequent total loss of time which it would involve would be inadmissible in a tramway with mechanical traction which has to accomplish its journeys in the short time specified in the regulations.

Messrs. Victor Popp and James Conti laid down the following problem : Given a certain number of compressed air chargers placed, for instance, every one or two miles apart along the tramway line, what device will enable the car to renew its supply at these stopping places, automatically, in a few seconds, without entailing any manœuvre on the public road, and without requiring that the driver shall leave his car ?

They solved this problem in a very simple manner, but the method they adopted is one of the features of their system.

The apparatus which enables the cars to take in a supply

of air along the road is called an *automatic air charger.* These are placed near the stopping places of the car.

Before and after the car has passed, a small rectangular cast-iron plate, placed between the two rails and flush with the road, is the only perceptible sign of the air charger. The automatic air charger may be said to consist of two parts—the

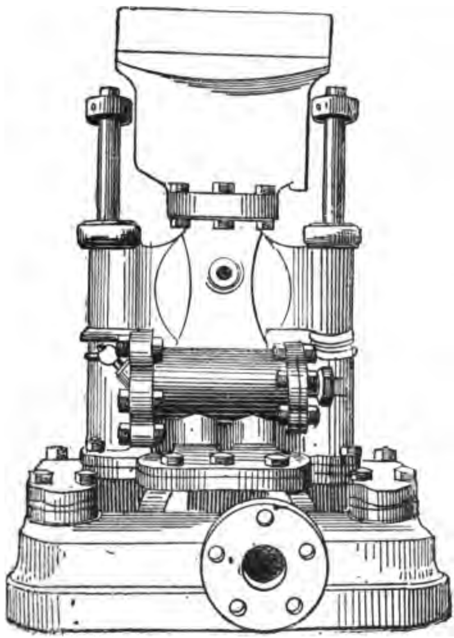


FIG. 52.—Distributor.

distributor, placed underneath the road at certain points along the line, and the reservoir, carried by the car.

The distributor is a hollow lenticular blade connected to the body of a pump, and is raised and lowered by means of compressed air (Fig. 52). When down, this blade is inclosed in a box, whose cover, which has the appearance of a grating,

can be seen from the road. When raised, the blade opens two small doors in the cover of the box, and stands about six

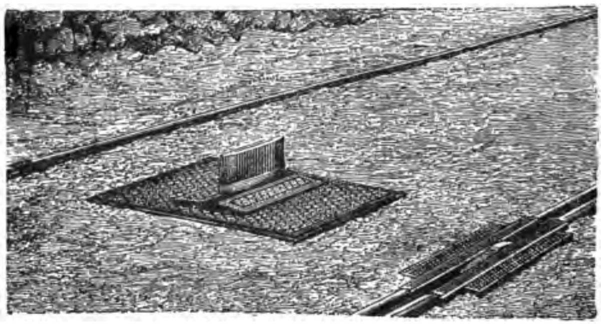


FIG. 53.—Distributor raised.

inches above the rail level (Fig. 53). It is ready in this position to fit into the receiver.

The distributor blade is raised by means of a pedal con-

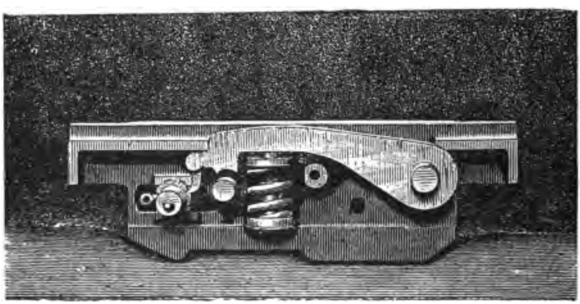


FIG. 54.—Pedal working the Distributor.

sisting of a lever placed between the rail and the guard rail, and is actuated by the flange of the wheel tyres (Fig. 54). This lever controls the admission of compressed air underneath the distributor blade. When the front wheel passes over the

pedal the weight of the car, acting on the lever, raises the blade, which remains in this position till the supply of air is concluded. Of course, the pedal can only be worked by the flange of the tramway wheel, because if any other car passes over the rail its wheel, being larger than the groove between the two rails, cannot touch the lever. Only a very light car would have a sufficiently narrow wheel to touch the pedal, but in that case its weight would not be enough to work it.

The receiver consists of a bronze box, closed at its lower end by two coil-springs placed side by side. When these springs are under pressure they bear against one another and form an air-tight joint. When, however, the pressure ceases, they allow the distributor blade to pass between them. This is the principle on which the supply of air takes place; we will describe the different stages through which this operation passes.

When the car arrives at the charger a flange of the front wheel of the car has already raised the distributor blade by means of the pedal. The rear wheel then passes over the pedal, and as the car travels on the blade comes between two guides, which lead it to the coil-springs forming the joint. A warning apparatus informs the driver that he has reached the precise spot, and he stops the tram; he has a margin of about three feet for stopping. He then opens a small cock before him. This operation has the following results:

1st. The pressure remaining in the reservoir passes between the springs and causes an air-tight joint around the blade.

2nd. This same pressure passes inside the receiver downwards into the blade, and causes a differential valve inside the latter to open and to establish connection between the main pipe and the receiver.

The compressed air arrives in the receiver, opens a retaining valve, and then passes into the car reservoir. When charging is finished the differential valve of the blade closes automatically as the air pressures in the pipe and the reservoir

are in equilibrium. The retaining valve in the reservoir then closes.

The driver knows that the reservoir is fully charged, firstly by the pointer of the air gauge, which becomes stationary, and secondly by an automatic whistle. He then closes the cock he had previously opened, the joint is released, and the blade falls.

The whole time taken by this operation does not exceed 15 seconds, and the car is then ready to start.

The efficiency of this system of traction is exceedingly good, on account of the low pressure used in the air reservoirs. Messrs. Popp-Conti's system is more economical than Mr. Mékarski's under this head, but we must remember that the prime cost is probably greater in the former than in the latter system, owing to the piping, which has to be laid under the road, for the automatic supply of air. In short, in our opinion the Mékarski system is preferable for a short line with frequent traffic, whilst for a long line we should be inclined to adopt the Popp-Conti system.

In concluding this chapter on compressed air auto-cars we will give a brief comparison of the efficiencies of the Mékarski and Popp-Conti systems of traction. We will not give the prime cost of the plant, as it varies according to the surrounding conditions, which latter may determine which of the two systems shall be adopted.

Efficiency of Compressed Air Systems.—By mechanical efficiency we shall mean the ratio of the power supplied by the steam motor at the central depôt to the corresponding work available on the wheels of the auto-car, and we will calculate the amount of this efficiency for the Mékarski and Popp-Conti systems.

Mr. Mékarski compresses air at 1,136 lbs. per square inch (80 kgs. per sq. centimetre), whilst Messrs. Popp-Conti do so at 355 lbs. (25 kgs. per sq. centimetre). We will assume that the pressures follow Boyle's law.

Let n represent the amount of compression; then the work done will be

$$W_c = p_0 v_0 \log' n.$$

Where p_0 is equal to one atmosphere or 10,000 kilogrammes per square metre; and as, for the purpose of comparison, we will assume we are dealing with a cubic metre of air, we shall have:

Mékarski, work of compression $W_c = 10{,}000 \log' 80$.
Popp-Conti, „ „ $W_c = 10{,}000 \log' 25$.
Mékarski $W_c = 45{,}200$ kilogrammetres.
Popp-Conti $W_c = 32{,}270$ kilogrammetres.

Supposing the efficiency of the compressors to be 0·75, the work done by the steam engines to compress 1 cubic metre of air will be:

$$\text{Mékarski } \frac{45{,}200}{0{\cdot}75} = 60{,}300 \text{ kilogrammetres.}$$

$$\text{Popp-Conti } \frac{32{,}270}{0{\cdot}75} = 43{,}000 \quad \text{,,}$$

With the Mékarski system there is hardly any loss of air between the compressed air reservoir and the compressor, whilst in the Popp-Conti system the air has to travel through the whole of the pipe in order to arrive at the automatic air charger. This loss, which we may estimate at 5 per cent., is therefore proportional to the length of the pipe. So that

$$\text{Popp-Conti } W_c = \frac{43{,}000}{0{\cdot}95} = 45{,}300 \text{ kilogrammetres.}$$

If the air were not re-heated before or during its expansion in the motor the temperature would fall considerably, and this might freeze the water vapour contained in the air, and also the lubricant. The efficiency would be very inferior, so that from every point of view it is advisable to re-heat the gases. Nearly all the heat given to the air before it passes into the cylinder is converted into useful work, and it is this

method of using up the heat which considerably raises the efficiency of compressed air systems. Evidently all the work expended to bring the air from the pressure of admission into the cylinder (about 10 atmospheres) to the initial pressure, which may vary from 355 to 1,136 lbs. per square inch, is completely lost. The efficiency of this conversion would therefore be extremely bad if the process of re-heating the air in order to increase their expansion had not been resorted to. In a word by utilising nearly all the heat destined for re-heating the air, we can compensate for the poor efficiency of compressed air systems. Messrs. Mékarski and Popp-Conti were aware of the importance of re-heating the air, and they have arranged hot water apparatus (about 250° Cent.) on their cars for the purpose of re-heating the compressed air before sending it into the motor.

This enables them to produce 22,000 kilogrammetres and over at 1 kg. of compressed air, whereas without re-heating they could not have obtained half this amount.

Supposing that the mechanical efficiency of the motor were equivalent to 0·65 on the average, we could easily calculate the useful work done per cubic metre of air.

$$W_u = 22{,}000 \times 1{\cdot}23^{\mathrm{kg.}} \times 0{\cdot}65 = 17{,}600 \text{ kilogrammetres.}$$

We shall therefore have :

Mékarski. Mechanical efficiency $\dfrac{17{,}600}{60{,}300} = 0{\cdot}29.$

Popp-Conti. ,, ,, $\dfrac{17{,}600}{45{,}300} = 0{\cdot}39.$

The Popp-Conti system has a great advantage over the Mékarski system in the amount of dead load to haul. The frame, motor, and reservoir are much lighter in the former, so that an auto-car for fifty passengers does not exceed 10 tons in weight. On the other hand, a Mékarski car for the same number of passengers would weigh 14 tons.

Therefore, to convey the same number of passengers, the

Popp-Conti system would require n horse-power-hours, and the Mékarski would require $1{\cdot}4\,n$ horse-power-hours.

Of course, these figures are not absolute, and will vary according to the distance that either of the cars under consideration has to travel.

In conclusion we will say that, although not very economical, traction by compressed air is to be recommended for traffic in towns because it is clean and produces neither noise nor smoke. The cars are easily managed, and can even be confided to drivers who have but little experience.

CHAPTER VI

PETROLEUM AUTO-CARS

THE DAIMLER MOTOR.

MESSRS. PANHARD & LEVASSOR, Peugeot, Gautier, and many other manufacturers employ Daimler motors on their cars. We may say that this motor is the king of motors for petroleum auto-cars, and therefore we will give it as complete a description as we can. Let us begin by a few words about the inventor.

Gottleib Daimler was born in 1834 at Schorndorf, a small village in Würtemberg. From his youth he showed remarkable aptitude for everything mechanical, and even before leaving school he had become a skilled mechanic. Having terminated his apprenticeship, Daimler worked in the most important manufacturing firms in Germany, and then came to England for a few years, where he was employed at the Whitworth Company's works. It is in these works that he acquired in a large measure the accuracy and skill which characterise the English mechanic.

After visiting various countries, Daimler, quite by chance, associated himself with Dr. Otto in the construction of gas motors. At that time Otto had not yet succeeded in constructing a practical motor, and it was only in 1872 that he and Daimler started the *Gas Motoren Fabrik* at Deutz, the necessary funds being provided by Privy Councillor Langen of Cologne. It was only ten years after that this enterprise became a profitable one.

Mr. Daimler was managing director of the works until

1882, and, giving Messrs. Crossley Bros., of Manchester, the benefit of his advice and experience, he assisted them in achieving the construction of their now world-renowned motor. He then left the *Gas Motoren Fabrik* and interested himself in the construction of a petroleum motor for high speeds and lighter than any which had hitherto been heard of. He designed all the parts of the motor known as the 'Daimler motor.' The preliminary compression and ignition by means of an incandescent tube are due to him, and his motor is still far and away the best of any in the market as regards weight, simplicity of construction, and reliability of working.

Daimler applied his motor to a bicycle in 1886, and to an auto-car in 1887. The results were exceedingly satisfactory, and the creation of this industry and the new impulse that has been given to road locomotion are entirely due to Daimler, and we might, in fact, call him the inventor of petroleum auto-cars and auto-cycles.

Fig. 55 shows a section of the latest pattern of Daimler motor, which is a great improvement on all the others hitherto built.

The motor has two cylinders, cast together, and working simultaneously. Whilst the gases are being exploded in one cylinder the other is drawing in the gaseous mixture which is to be fired during the next stroke, so that for every revolution there is an explosion either in one cylinder or the other, thus insuring regularity of speed without requiring a heavy flywheel.

The disc *F* and the two rods *B* are inclosed in an air-tight casing *E* to protect them from dirt, dust, &c.

The crank shaft *A* passes through stuffing boxes. The shell *E* is partly filled with oil, so that the rods, disc *F*, and crank shaft are always lubricated; the oil projected by the working parts insures the lubrication of the cylinder.

This motor, like all the Daimler motors, is an Otto-cycle motor, and passes through the following phases during two

revolutions: Drawing in of charge, compression of charge, explosion and expulsion of burnt gas. We will now examine how these operations take place.

The gas is drawn in by the action of the piston. As it descends it creates a vacuum, and the valve *m*, which is kept on its seating by a small spring, is opened by atmospheric pressure

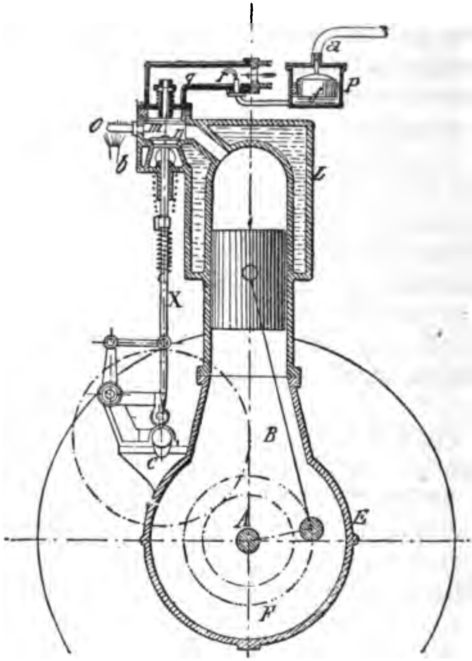


FIG. 55.—The Daimler Motor.

and allows the gaseous mixture to pass through the tube *q*. The cut shows how the air and petroleum vapours are mixed. The float chamber *P* is connected with a petroleum reservoir; a float *f* regulating the supply of petroleum so that it may never rise above a certain level in *P*. When the petroleum is at the required level the float automatically closes the supply

pipe *a*, and only opens it again when the level falls. The petroleum is therefore always brought to the jet *r* at a constant pressure, and is vaporised at that point by means of the induced draught created by the motor. The air thus carburetted passes through the valve *m* into the cylinder till the piston is at the end of its stroke. The pressure of the gas is then lower than atmospheric pressure by a certain amount proportional to the tension of the spring of the valve *m*.

It follows, therefore, that the amount of compression at the end of the return stroke of the piston is not equivalent to the ratio of the dead space to the total volume occupied by the gas. The compression of the gas can therefore be varied within certain limits, according to the tension of the spring. Mr. Daimler usually adopts a pressure of from 42 lbs. to 56 lbs.

The explosion takes place after compression as the piston is starting on its second forward stroke. The charge is fired by means of a platinum tube *O* heated to incandescence by a burner *b*, which is brought into contact with the gaseous mixture at the required moment by means of a slide valve.

This additional valve is often dispensed with in small motors, and the explosion is arranged to take place automatically instead by making the platinum tube of such a length that the burnt gas in the clearance space of the cylinder is driven sufficiently far after compression to enable the explosive mixture to come into contact with the heated portion of the platinum tube. The length of the platinum tube, which may be varied by pushing it in more or less, will regulate the motor for different degrees of ccmpression.

This method of obtaining ignition at the required moment is not to be recommended. For instance, if the degree of compression should alter, owing to a leak or because the tension of the spring of the admission valve is too great, the explosive mixture would no longer be able to come into contact with the incandescent tube, and ignition would therefore not take place.

On the return stroke the gas is expelled through the valve *n*, which is lifted by a rod *X* raised by a cam *c* on a small shaft.

This shaft revolves at half the speed of the main shaft, so that the cam *c* only raises the rod *X* every other revolution. The latter is hinged to a set of levers, and can be displaced from its normal position by a regulator working by centrifugal force if the speed of the motor exceeds a certain limit. The cam *c* then no longer touches *X*, so that the valve remains on its seat. The burnt gas will therefore be compressed and then expanded during the following forward stroke, which is the suction stroke, without a fresh supply of gas coming into the cylinder. This does away with one explosion, and enables the motor to return to its normal speed.

As we have said, the motor consists of two cylinders, cast together, and working as we have already indicated. They are slightly inclined to one another, but the piston connecting rods work on the same disc *A*. This arrangement gives one explosion per revolution.

The same regulator for the supply of petroleum is used for both cylinders. Petroleum from the large reservoir on the car is supplied by means of a small air pump, which is part of the motor, and is worked by a small portion of the gas coming from the exhaust. This pump is also used to send petroleum into the burners *b*.

The two cylinders are cooled by circulation of water in the jacket *L* which surrounds them. After passing through this jacket the water goes into a hollow flywheel, which is revolved by the motor, the object being to cool it by assisting evaporation. The cooled water from the hollow flywheel is caught up by a collecting pipe and sent by centrifugal force into the reservoir placed in the fore part of the car; from there it passes again into the jacket surrounding the cylinders.

We will conclude our remarks on the Daimler motor by

calling attention to the simplicity and strength of the parts. No lubricators, only two valves, one explosion per revolution, an automatic carburator, unfailing circulation of water, high velocity of rotation (700 revolutions per minute); these are the features of this motor.

To avoid vibration, Daimler suspends the motor on springs fixed to the car body and works the shaft by means of four belts. In normal working these belts are slack, but any one of them can be tightened by a lever, so that four different speeds can be obtained. The intermediate shaft works the driving wheels by means of a pinion and a pitched wheel fixed to one of the driving wheels.

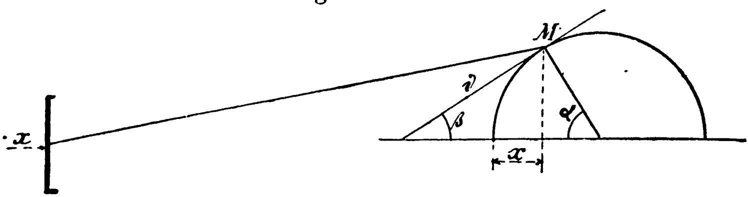


FIG. 56.

The main objection which is found with the Daimler motor is that it is not *balanced*. The two pistons and the two rods fall at the same moment, so that the masses in movement change from a downward velocity v to an upward velocity $-v$. The total change for each complete stroke is therefore $2v$, which is sufficient to cause considerable pressure on the crank pin.

Let us look at Fig. 56 to understand the disturbing effects which this change in velocity may have, and let us find the extent of pressure on the crank pin M caused by the moving mass.

Let P equal the weight of the piston and crank, and let us find the velocity and acceleration of the mass $\frac{P}{g}$ at each instant.

For the sake of simplicity we will assume that the crank revolves uniformly, and we will call v its circumferential velocity at the point M; we will also assume that the connecting rod is of infinite length.

The velocity of translation of the rod will be expressed by

$$v' = \frac{dx}{dt} = v \cos \beta = v \sin \alpha,$$

so that acceleration,

$$\gamma = \frac{dv'}{dt} = v \cos \alpha \frac{d\alpha}{dt} = \frac{v}{r} \cos \alpha \, r \frac{d\alpha}{dt}.$$

But

$$v = r \frac{d\alpha}{dt};$$

whence

$$\gamma = \frac{v^2}{r} \cos \alpha = \frac{v^2}{r} \frac{r - x}{r} = \frac{v^2}{r^2} (r - x).$$

The pressure on M due to the moving mass will therefore be

$$(A) \qquad p = \frac{P}{g} \gamma = \frac{P}{g} \frac{v^2}{r^2} (r - x).$$

If we erect ordinates to represent the valves of p and abscissæ to represent the travel of the piston we shall obtain the diagram shown on Fig. 57.

We find graphically that at the commencement of the stroke the pressure at M is positive, and tends to impede the working of the motor. This pressure changes direction at the middle of the stroke, and at the end accelerates the velocity of the point M.

At the beginning of the return stroke the reverse takes place, and the pressure again tends to stop the motor. The direction of the pressure on the crank pin has therefore remained unaltered, but this, however, is not the case at the beginning of the forward stroke, which produces explosion.

The explosion will propel the mass forward and tend to increase the velocity of the motor rather than diminish it. Instead of stopping the motor the sudden change of direction of stress will have the contrary effect, and if there is any play in the head of the connecting rod the parts will rattle. As we have already seen, the stress alters in direction at the middle of each stroke when no explosion takes place.

The simplest way to avoid the great pressure due to the moving parts at the beginning and at the end of each stroke is to set the two cylinders in opposition. The resulting pressure due to the action of the masses on the two pistons and the two crank pins will be zero, as shown on Fig. 57. The engine will be *balanced*, and there will be neither jarring nor vibration.

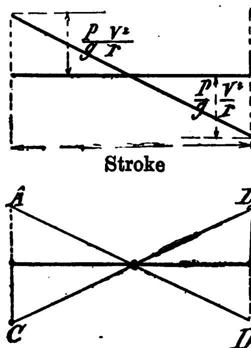


Fig. 57.

Mr. Daimler has, no doubt for practical reasons, not thought it advisable to adopt this arrangement, so that his motor is somewhat noisy. The spring supporting the motor deadens the vibration to a great extent.

We cannot give the exact consumption of this motor, but from what we hear it is below 0·11 gallon of petroleum at 700° per horse-power per hour.

THE PANHARD-LEVASSOR PETROLEUM CAR.

Messrs. Panhard & Levassor have, during the last ten years, been occupied in the construction of petroleum auto-cars. They have adopted the Daimler motor for their carriages, and the inventor himself came to their works to instruct them regarding its manufacture, and they have acquired the exclusive patent rights for France.

After many years' experience, and assisted by the inventor, Messrs. Panhard & Levassor have at length succeeded in building a really strong and practical pattern of car. We have only to refer the reader to the Paris-Bordeaux race which took place last year in order to demonstrate the value of Messrs. Panhard & Levassor's car. Mr. Levassor covered the distance from Paris to Bordeaux, 744 miles, with his No. 5 car for two passengers, in 48 hours and 47 minutes, averaging a speed of about 15½ miles per hour. What more do we require, and where is the locomotive that could travel from Paris to Bordeaux and back without stopping and without cooling its working parts? There is probably none.

No doubt, however, the victory of No. 5 car, which arrived about five hours before the others, was in great measure due to its able and energetic driver, Mr. Levassor.

The latter drove with a daring which may have been dangerous to himself, but which never affected his car. He never overworked it so as to fatigue the working parts, and he ran it below rather than above its normal power. He did not confide the task of working *his engine* to others, but he watched its every freak during the 48 hours he was on the road.

Fig. 58 shows a general view of the motor employed, which, as we have said before, is of the Daimler pattern.

There is an automatic feed, and the expulsion of the burnt gas is mechanical, and controlled by a valve which, by the arrangement already described, is only lifted when the speed of the motor exceeds its normal speed. In that case no fresh charge is admitted during the following stroke, there is no explosion, and the motor slacks speed. The power is transmitted to the driving wheels by means of pitched chains and wheels.

Mr. Levassor would not give us any new information on the motor itself, so that, as we have already described the Daimler motor, we will not dwell upon the pattern which has

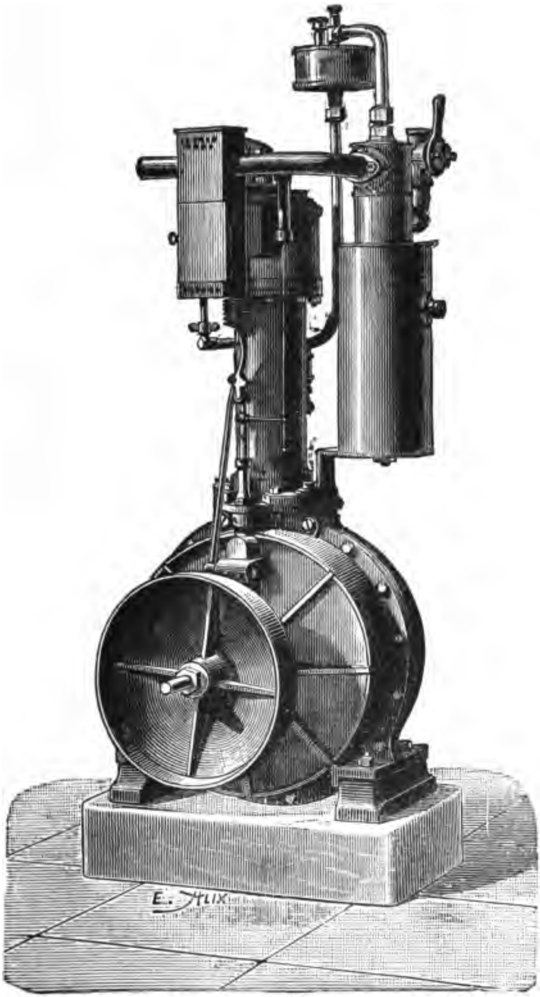


FIG. 58.—The Phœnix Motor (Daimler system).

been applied to these cars. We may say, however, that, as in the Daimler motor, ignition takes place by means of an incandescent tube at the moment when the fresh gas has been compressed sufficiently to come into contact with the tube, notwithstanding the small quantity of burnt gas which has been driven to the end of the cylinder. Explosion takes place when the piston is at about one-eighth of its downward stroke.

FIG. 59.—Car seating two, with hood.

Like the Daimler motor, this motor is not balanced, and consequently gives rise to vibration.

Fig. 59 shows a general view of No. 5 car, which won the Paris-Bordeaux race. The parts under control of the driver consist of a steering lever—the front axle being of the divided-axle type—a reversing lever, the brake, and the regulator which controls the supply of petroleum into the carburator.

These cars run very well, and those who have employed

them state that they require little maintenance, and that a little petroleum oil poured into the cylinders from time to time is quite sufficient to clean them. They can run at a speed of from 11 to $15\frac{1}{2}$ miles on the level, and at an average speed of 5 miles on banks.

THE PEUGEOT CAR.

The three cars which came in next after Mr. Levassor's were all Peugeot cars. According to the regulations drawn up for the race, the first prize could only be given to a car

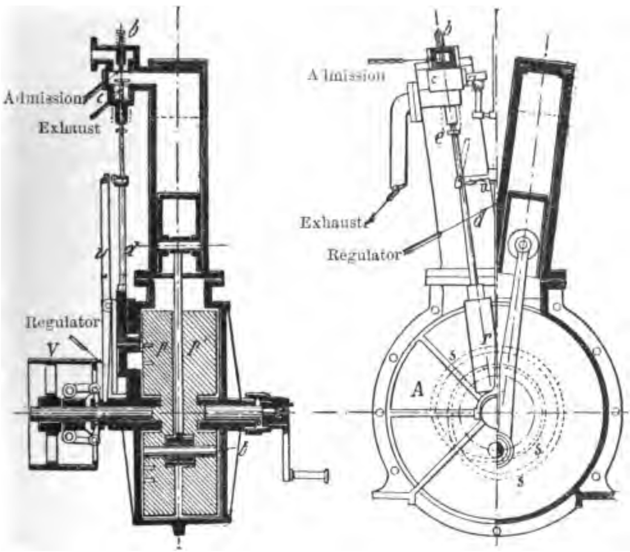


Fig. 60.—Daimler Motor applied to the Peugeot Cars.

for four passengers, so that, although it arrived fourth, the Peugeot car for four passengers took the first prize of £1,200.

Again we find the Daimler motor, built by the firm of Panhard & Levassor, employed for driving these cars.

From Fig. 60 we see that the motor adopted is practically

the same as the Daimler motor. The general arrangement of the car presents some novel features. The arrangement adopted by the firm of Peugeot is shown on Fig. 61.

The motor *A* and the carburator are fixed to the tubular steel framing of the car. By means of the clutch *G* the motor

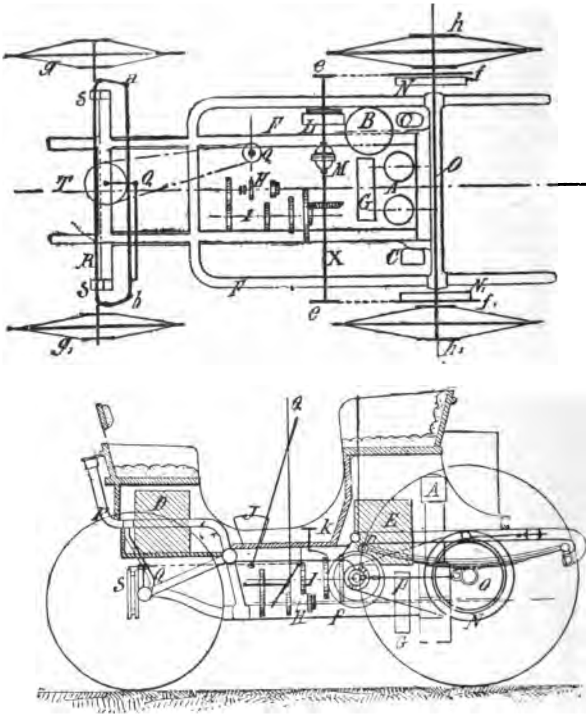


FIG. 61.—Machinery of Peugeot Car.

may be caused to work an intermediate and movable shaft which carries three steel pinions, *H*. This shaft is moved forwards and backwards by means of the lever *Q*, which throws the motor in or out of gear. The position of the lever *Q* determines which of the three pinions will engage the

toothed wheels I, which correspond to the different speeds of the motor. The shaft carrying the wheels I transmits the power by means of two bevel wheels to a third intermediate shaft, which in its turn transmits the movement to the wheels by means of two Gall chains ee_1. This gearing is rigidly fixed to the framework of the car, and the driving wheels are attached to two elastic plate springs. The fore body is hung upon a single spring, which is fixed in the centre to the frame of the car by a trunnion, T, and is connected at the ends to the fore axle by means of two small cranks, a and b, as shown on Fig. 62.

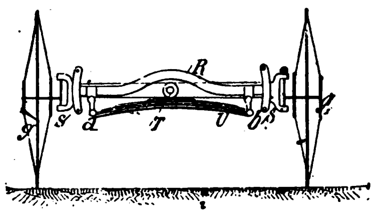


Fig. 62.

The axle has therefore two movements : it swings around the trunnion and has an oscillating motion at a and b as the spring bends. These two movements are generally synchronous, the axle being guided by two slides, S. In this manner the seat is always horizontal, whichever of the wheels is lifted by the uneven road. The fore-carriage is of the divided axle type, and steering is effected by a lever which commands a toothed wheel, Q, connected to the steering wheel by a chain.

Class of car	H.P.	Approximate weight of car	Length		Width		Maximum load including driver
		lbs.	ft.	ins.	ft.	ins.	lbs.
Car, 2 seats . .	$1\frac{1}{5}$	880	7	1	4	4	330
Vis-à-vis . . .	$2\frac{1}{3}$	1,320	8	5	4	8	660
Phaeton . . .	$2\frac{1}{2}$	1,320	8	9	4	8	660
Victoria, 3 seats . .	$2\frac{1}{2}$	1,276	9	1	4	8	550
,, 4 ,, . .	$3\frac{1}{4}$	1,430	9	1	4	8	704
Break	$3\frac{1}{4}$	1,650	8	10	4	8	880

The car is also provided with a water tank, E, for cooling the motor, and with two brakes working together on either of

two pulleys, N and N_1, fixed to the driving wheels, and on an intermediate shaft, L. The foregoing small table gives the dimensions and weights of the various patterns of cars built by Messrs. Peugeot.

We may add, to complete this information, that the expenditure of petroleum varies from ·64*d.* to ·80*d.* per mile, and that the consumption of oil is unimportant. The petroleum tank holds from 4½ to 5½ gallons, according to the pattern of car, and the amount of water required for cooling the cylinders varies from 5½ to 9 gallons.

The Peugeot cars are often fitted with ball bearings.

The spokes, similar to those used for bicycles, are of mild steel, and have a resistance of 63 tons per square inch of section. They are very serviceable, never break, and are easily replaced by means of a special key, which is provided with the car.

Wheel spokes have called into existence quite a special industry derived from wire-drawing, which, however, we cannot describe here. The first spokes employed were straight, but now they are nearly always tangential, and are easier to repair and replace, possessing at the same time great elasticity. These spokes are made in different kinds of steel—soft, mild, or extra hard steel.

Mr. Beaujouan, the well-known electrical engineer, has written an interesting paper on cycle manufacture, published in the 'Génie Civil' of April 13, 1892, and in 'Cosmos,' August 11, 1894, in which he quotes as follows Mr. Jonte's views on the resistance of spokes :

'The well-known expert, Mr. Jonte, engineer, E.C.P., late manager in Paris of the Forges de Franche-Comté and consulting engineer to the Ministry of Commerce, carried out experiments on wires for suspension bridges, for telegraphic purposes, and for mining and marine cables, and found that the strain on spokes never exceeded 13 tons per square inch of section. Bicycle spokes stand 47 tons and over (the average is 63 tons per square inch).'

This interesting paper explodes the old idea of 126 and even 157 tons per square inch, though of course it is not wholly impossible.

In fact, the use of a very hard steel would render the spokes brittle at their bent or threaded parts, and consequently it would be impossible to have a screw thread on a spoke of 0·079 *inch* diameter which would resist a tension of 48 tons per square inch.

No spoke has yet been found to break under normal working strain at any part except the threaded part.

Ball bearings being used so extensively, especially for bicycles, Messrs. Peugeot, whose bicycles are so well known, saw at once the advantage of adopting ball bearings for auto-cars.

Rubber tyres were also found applicable to such light cars. The tyre round the wheels consists of several layers 0·19 inch thick. Those employed by Messrs. Peugeot are made by the firms of Torrilhon and Edeline.

Small cars need only have one row of balls; but for cars weighing 6 tons and over ball bearings with two or three rows of balls should be used.

In building these cars Messrs. Peugeot have borrowed many ideas from bicycle construction, and have happily assimilated them to the new vehicle.

The car frame is of steel tube drawn cold, and the joints are of wrought or cast iron.

These cars have great resistance for small weight, and the water for cooling the cylinders can be cooled by being passed through the tubular framing of the car.

THE ROGER CAR.

These petroleum cars are not yet very well known, although they are first-class cars, strong, well built, and employ an exceedingly simple motor, which can easily be examined and taken to pieces without the assistance of a skilled mechan-

Fig. 63 is a general view of the car; its elegant appearance leaves nothing to be desired. Fig. 64 shows the arrangement of the machinery and reversing gear.

The chief features of this car which distinguish it from others are the following :—A Benz motor is employed; it is an Otto-cycle motor with a single cylinder, *A*; the valve motion is reduced to a minimum, as we shall see later on; the motor works at 300 revolutions per minute only, and is fixed horizontally, which avoids those up and down vibrations which are the great drawback of the Daimler motor. It is placed at the rear of the car within reach from the ground, and all its parts are visible and accessible. Belting is used, which, spite of its drawbacks, at least dispenses with wheel gearing and jolting on uneven ground. The main disadvantage of belts is that they require frequent adjustment, as they expand in damp weather.

The front wheels steer, and the fore-carriage is of the divided axle type, and there is no lateral strain on the wheels.

The average speed of the car is thirteen miles an hour on good roads.

We believe that a company has just been formed for working Roger auto-cabs. The machinery is so simple that no doubt ordinary cabmen will be able to drive these auto-cars. We think, however, that this attempt is somewhat premature, and we should have preferred to wait for a newer and more perfect car before taking this decisive step, which will decide whether petroleum auto-cars are capable of fulfilling the requirements of a cab service.

The Benz Motor.—The Benz motor applied to the Roger car is an Otto-cycle motor with electric ignition. Before describing it we will say a few words regarding the single-cycle Benz motor, which has certain interesting points.

Figs. 65 and 66 are two sections of the motor. Owing to the draughtsman's mistake, the piston is shown in two different positions on these cuts. The valve gear consists of three ordinary valves, *a*, *b*, and *S*, and a slide, *E′*, which enables the

following operations to take place :—Forward stroke : explosion of gas mixture and compression of fresh air in a reservoir, *E*.

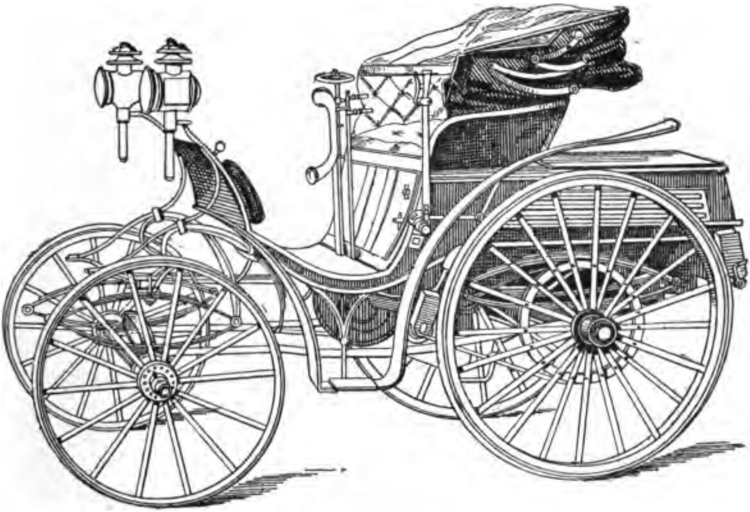


FIG. 63.—The Roger Car.

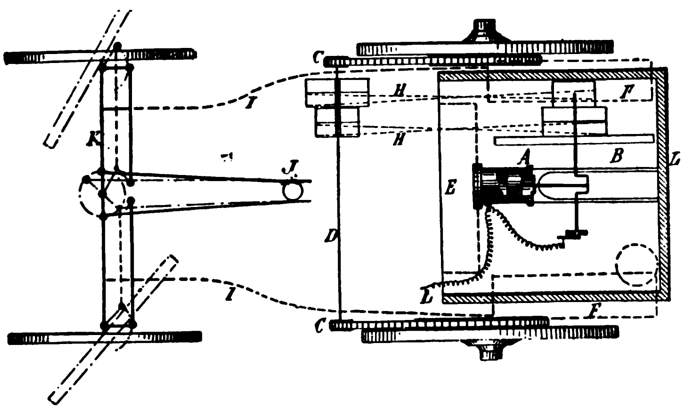


FIG. 64.—Machinery of the Roger Car.

Return stroke: expulsion of burnt gas, automatic exhaust, and a compression of fresh gas mixture.

This is what takes place :—During the forward stroke the

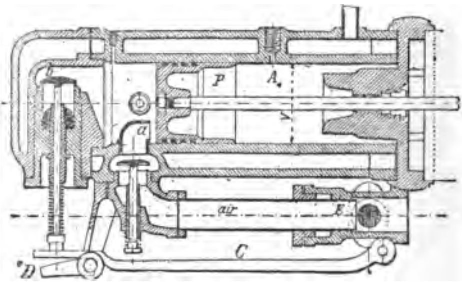


FIG. 65.—The Benz Motor (section).

gas, compressed in the clearance space of the cylinder, is ignited by an electric spark at a plug, *c*, by an arrangement described below.

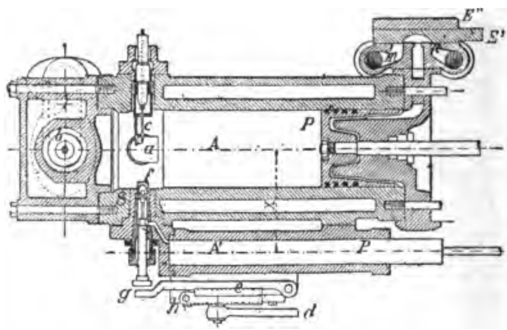


FIG. 66.—The Benz Motor (section).

On the other side of the piston the fresh air previously in the cylinder is driven through a hole in the slide *E′* into a special reservoir, *E*. At the end of the stroke the slide *E′* cuts off the reservoir *E* and allows the lower part of the cylinder to communicate with external air, so that during the return

stroke a fresh supply of air is drawn into the cylinder ready to be driven into the reservoir *E* during the next forward stroke. During the return stroke the burnt gas is expelled through the valve *b* into the atmosphere, and in order to clear the cylinder thoroughly the valve *a* is open when the piston is midway on its return stroke, so that all the air contained in *E* sweeps the cylinder and rushes out at *b*. The valves *a* and *b* then close automatically, and the fresh air contained in the cylinder is compressed till the end of the stroke. At the same time a pump, *A*, injects petroleum vapour into the cylinder through the valve *S*, which is opened automatically by a lever, *g*, and the explosive mixture thus made is then ready for firing at the beginning of the next stroke.

We have no precise information regarding the carburator, but probably the pump *A′* simply communicates with a slightly heated reservoir of petroleum spirit, so that during the forward stroke the pump would draw in petroleum vapour through a small valve, which would close automatically whilst the carburetted vapour was being drawn into the cylinder. The igniter is placed at the side of the cylinder.

A small magneto-electric machine, formed by a coil and permanent magnets, is worked by a small shaft and band, producing an electric current. One pole of the coil is connected to one of the wires in the plug *c*. The outside of the plug is connected to the body of the motor, and the other pole of the coil makes contact with the latter, when ignition has to take place, by means of a cam and set of levers, which make and break contact at the required moment.

This motor was not found suitable for the Roger car on account of its numerous and cumbersome parts, but we think it might be simplified, and, as volume for volume of cylinder it would give twice as much power as an Otto-cycle motor, it is a pity it has not been adopted for cars. The motor couple would also be much more constant, and suitable water-jacketing would prevent any heating due to the great number

of explosions. Its complication is its only drawback, in our opinion.

The Otto-cycle Benz Motor.—This motor is practically similar to the one just described. It is much simpler, however, as the cylinder has an open end and the gas is no longer compressed before being passed into the motor. The slide and valve gear can therefore be dispensed with, so that only two tubes are required, for admission and exhaust. Although horizontal, care must be taken that these valves close properly on their seats.

THE GLADIATOR AUTO-CYCLES.

Not content with their reputation for cycle manufacture, the Gladiator Company, whose technical expert is Mr. Darracq, have lately designed three new types of auto-cars—a tricycle, a quadricycle to seat two, and an elegant little car which everyone will have noticed at the last cycle exhibition in Paris.

Figs. 67, 68, and 69 are cuts of these three cars.

The quadricycle and car motors are practically the same, both being horizontal, whilst the tricycle has an upright motor.

The latter is placed to the fore of the tricycle, and works the rear wheel by means of two pitched chains and an intermediate shaft, which carries cranks and pedals like an ordinary tricycle. This arrangement enables the rider to assist the motor on heavy ground or up steep banks, and also to start it, which latter operation, on auto-carriages, requires a special handle.

The front wheels steer, and are fitted to a divided axle; they are worked by the tricycle handle bar.

Exhaust takes place in the lower part of a box containing the gasoline reservoir with the object of assisting vaporisation. The amount of carburetted vapour drawn with the air into the motor is controlled by a regulator.

The motor described below makes 600 revolutions per

minute; it can develop $\frac{2}{3}$ horse-power, sufficient for a speed of $15\frac{1}{2}$ miles an hour on good roads.

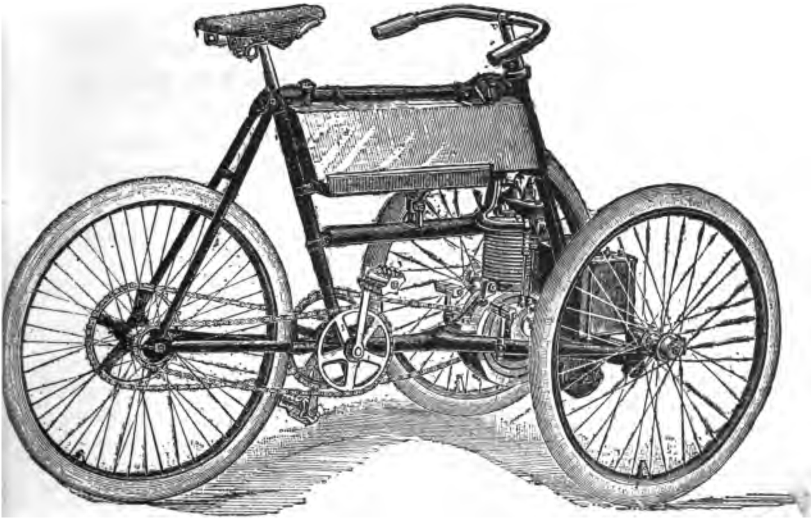


FIG. 67.—The Gladiator Tricycle.

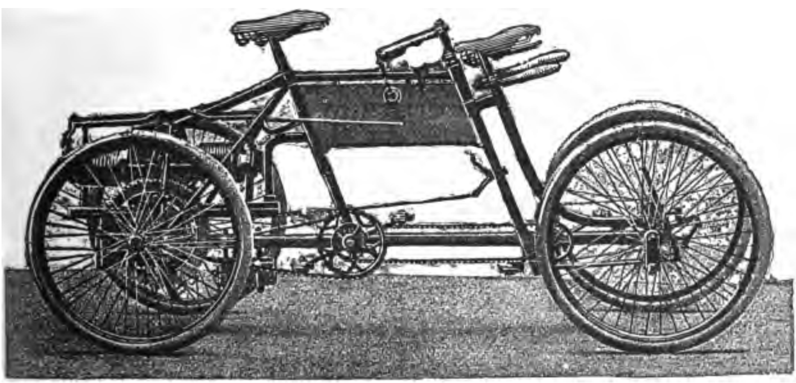


FIG. 68.—The Gladiator Quadricycle.

There is nothing special in the arrangement of the quadricycle, Fig. 68. The front wheels are steered in the same way as those of the tricycle. The rear wheels drive, and have a differential gear. The motor works them by means of toothed wheels, and, similarly to the tricycle, two pairs of pedals are provided for assisting and starting the motor. The latter cannot be thrown out of gear, but when the car is pushed by hand compression can be dispensed with; the same applies to the tricycle.

The quadricycle motor can supply 2 horse-power, is similar

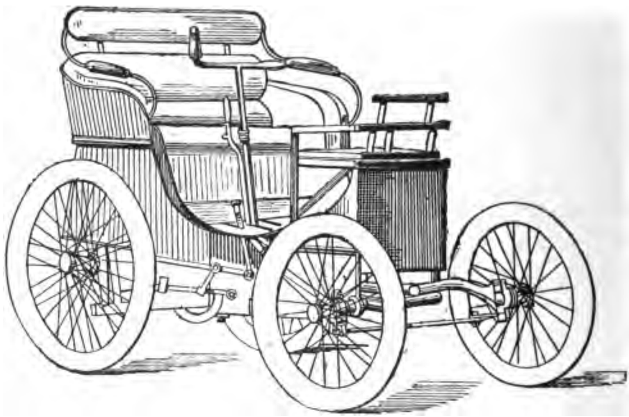


Fig. 69.—A small Gladiator Car.

to the tricycle motor, and has also the drawback of not being balanced.

Fig. 69 shows an elegant and light little car to seat two. It is steered on the divided axle principle, has a reversing lever, and its regulator controls the admission of the petroleum vapour.

The car weighs only 440 lbs. when loaded, that is to say, with 4·8 gallons of water, 4·4 gallons of petroleum at a density of 680° to 710°, and 0·66 gallon of pure mineral oil.

This supply of petroleum suffices for a run of 15 hours at $15\frac{1}{2}$ miles an hour over ordinary ground.

The motor weighs 110 lbs., and has an average speed of 500 revolutions per minute and nearly 4 effective horse-power.

The car is arranged to travel at two different speeds, intermediate speeds being obtained by controlling the supply of petroleum.

We are indebted to Mr. Darracq for the working drawing of the car motor which we have reproduced on Fig. 70.

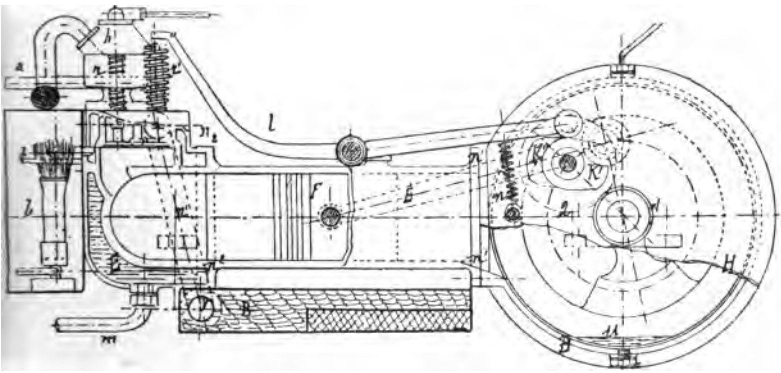


FIG. 70.—Motor of Gladiator Car.

It is horizontal, and has two parallel cylinders, only one being shown on the cut. The motor consists of three cast-iron parts, bolted together at $n_1 n_1$ and $n_2 n_2$. The first casting comprises the explosion box and the cylinder bottom, the second the cylinder barrel, and the third the air-tight casing in which the crank revolves immersed in oil.

The whole could have been cast in two parts, but for practical reasons it was found much easier not to do so, as the advantages of a joint the less and greater simplicity would have been neutralised by difficulties in casting and turning the parts.

The two cylinders, of which we shall only describe one, work simultaneously, but explosion takes place in one cylinder whilst the other is drawing in the gas, so that we have one explosion per revolution, as in the Daimler motor.

It is an Otto-cycle motor, and is kept cool by a water-jacket, *E*, surrounding the explosion chamber only. The pipe *m* leads to an apparatus for cooling the water. A Longuemarre burner at *b* is connected with a special reservoir of mineral oil. To start the burner it is necessary to keep up a certain pressure in the oil reservoir during a few moments by means of a small pump; but once the motor is started the supply is automatic. The burner is used to raise to a white heat a small tube of platinum, *t*, which ignites the gases.

Petroleum vapour is supplied through the pipe ρ, and air through the pipe *a*. Mixture takes place in the chamber *G*, and can be regulated by the key *R*. Any kind of carburator being suitable, no description is needed.

The charge is drawn automatically through the valve *s*, which has a spring, *r*, closing it after each suction. The valves and valve seatings are made of cement steel, and thoroughly fitted to avoid friction and consequent wear, which might cause leakage. The valve s' has a powerful spring, r', and is worked by the lever *l*, which presses upon it so as to open the valve every alternate revolution, this being accomplished by means of a cam, K', fitted to an intermediate shaft revolving once to every two revolutions of the main shaft.

The toothed wheels, 1 and 2, shown in dotted lines, have a ratio of 1 to 2, so as to obtain the required reduction of angular velocity. The cam K'' is keyed to the same shaft as the cam K' at an angle of 180 degrees to it; it raises the lever belonging to the other cylinder, so that exhaust takes place in the second cylinder one revolution later than in the cylinder under consideration, as the intermediate shaft only revolves half as quickly as the main shaft.

The spring *n* keeps the lever *l* in contact with the cam K'.

The exhaust gas passes through the pipe n_1 into the box *B*, which is divided into two compartments full of steel filings, which deaden the noise of the exhaust. The heavier filings are placed near the air outlet, so that there is less resistance to the passage of the gas as the outlet is approached, and the gas can expand gradually before finally escaping.

The ratio of the total volume at the end of the forward stroke to the volume swept by the piston is about $\frac{24}{15}$, so that compression at the end of the stroke attains about 22·72 lbs. per square inch. This amount of compression is rather slight, and probably after explosion the pressure does not greatly exceed 142 lbs. or 170 lbs. per square inch. The length of the tube *t* is such that the fresh gas only comes into contact with the incandescent portion at the end of compression, after the burnt gas from the previous explosion has been driven away.

The drawing on Fig. 70 is to scale.

The motor of the quadricycle differs slightly from the above. It is horizontal, but the two cylinders are in opposition, and the two connecting rods of the pistons are attached to the same crank pin. The motor consists of four castings: the explosion boxes and bottoms of cylinders, the cylinders and the casing made up of two parts bolted together.

There is no water jacket, but the cylinder has plain ribs cast on to it, which enables the surrounding atmosphere to do all the cooling that is required. The gas is ignited by an electric spark at the end of a plug containing the wires.

The two valves in each cylinder are horizontal, which is not a suitable arrangement. They are worked mechanically by two cams fixed to an intermediate shaft revolving at half the speed of the main shaft. This reduction in speed is obtained by two toothed wheels having a ratio of 1 to 2.

As in the car motor, one of the cylinders is drawing in the charge while the other is exploding it. The valves close on

their seats by means of springs. The crank consists of two discs keyed to the main shaft and connected together by the crank pin; they dip into the oil contained in the air-tight casing, so that the machinery of the motor is well lubricated.

Each piston has a 3-inch stroke, and the amount of compression is practically the same as in the car motor. The motor has a speed of about 400 revolutions per minute, a power of 2 effective horse-power, and consumes about 0·11 gallon of petroleum per horse-power per hour.

The car motor supplies over 4 horse-power for the same speed, as the stroke of the piston is double and the area of each piston is greater than that of the one just described.

The electric spark is produced very economically, two cells, a Ruhmkorff coil, and an igniting plug being all that is required. Normally the current does not pass through the coil, whose contact piece is kept off by a small grooved cam; when the groove of the cam comes into play the commutator is freed, and oscillates several times before being kept off again by the cam. Consequently, as the current only passes through the coil at the precise moment it is required for producing the spark which explodes the gas, this method is economical, as there is no needless expenditure of electricity.

The Gladiator motors are well designed, and although, like the Daimler motors, they have the disadvantage of not being balanced, we do not see that they are in any way inferior to the latter.

Mr. Darracq tells us that he is designing a new motor which is a great improvement on existing ones. We shall be glad to see this carried out successfully, as gas motors for auto-car purposes are still far from perfect; they are too noisy and difficult to manage.

THE DURYEA CAR.

A Duryea car was the first to arrive in the competition organised by the 'Times Herald' in November 1895.

The motor employed on the Duryea car is, like the Kane-Pennington motor, an American invention. These motors both mark an important step in advance over those which have hitherto been in the market, and will excite the interest of those who follow the question of self-propelled traffic.

The Duryea car, which came out victorious in the recent contest, may therefore have a brilliant future before it, and it would be unfair to ignore its good and practical qualities.

The following information is taken from the English patents regarding this motor and its application to a car.

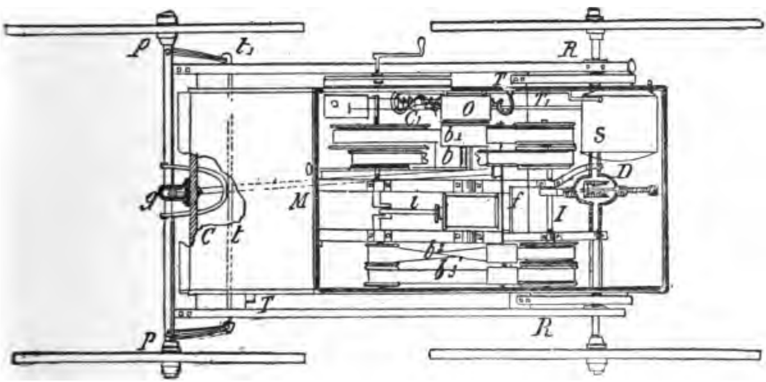


Fig. 71.—Plan of Duryea Car.

The *Autocar* of Coventry has already published a description of the motor employed on this car.

The car (Figs. 71 and 72) has four wheels, the driving wheels being at the rear. The motor is suspended to the car frame, and by means of gearing and a pinion keyed to the intermediate shaft *I* the power is transmitted to the differential *D*, which works the two driving wheels. This differential shaft is mounted on two springs, *R*, which bear against the frame.

The lever *M* and two rods *t* and *t′* are used for the steering,

which is on the divided axle principle. This method of steering, however, differs from similar systems in the mode of suspension adopted, the fore-carriage being suspended to a transverse spring, *T*, so that the front axle is enabled to turn upon a trunnion, *C*.

It will be seen that this arrangement has the advantage of enabling the front wheels to go over rough ground without bringing any strain upon the framework of the car. We may notice also that the wheels have pivots *p* inclined to the vertical, and this arrangement not only assists steering, but

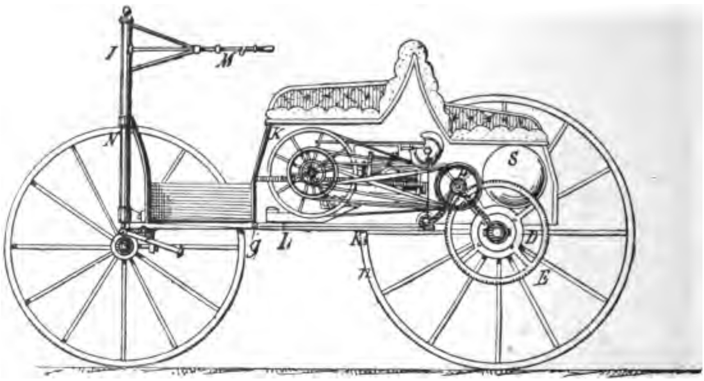


Fig. 72.—Section of Duryea Car.

also prevents the wheels from suddenly deviating from their path on encountering any obstruction on the road.

The handle *M* has a catch which fits into notches and varies the speed of the car. This is what takes place : By raising or lowering this catch, a cord, shown in dotted lines on the drawing, is pulled. This cord follows the tube *N* and passes on to the pulley *f*, being guided by rollers, *g* and *g'*. By moving *M* we pull the cord, and thereby revolve the pulley *f*, which works a shaft carrying four different cams, which, according to the position of the shaft, stretch either of four belts connecting the driving shaft *K* with the intermediate shaft *I*.

By working M we can therefore stretch either of the belts b, b_1, b_2, or b_3, which correspond to different velocities of the car compared to that of the motor; reversing can also be effected by these means.

The motor *per se* is quite different from those which have hitherto been built.

Explosion does not take place in the cylinder itself but in a special reservoir, O, which in this case is equivalent to the boiler of a steam-engine. The reservoir O supplies gas under pressure to the cylinder. The gasoline or other petroleum spirit, which is stored in a receiver, S, passes through a pipe, T, branched at its lower end, and into a large tube, C, where it is evaporated by the action of heat.

The petroleum vapour then passes into a burner provided with a tube discharging into a reservoir, O. In passing through this tube the gas carries away the necessary amount of air for its combustion, which takes place in O. Another pipe, T_1, starts from O and leads to the upper part of the receiver, S, so as to maintain a uniform pressure in the whole system S, T, C_1, and T_1.

Without this arrangement the pressure of gas in O would, by acting in C_1 and S, evidently prevent the gasoline from falling and evaporating in C_1. The tube T is provided with a conical valve which, according to its position, regulates the supply of petroleum. All things being equal, the pressure will always be proportional to the quantity of hydro-carbon which passes through per second, so that once the valve has been regulated for a car it need never be touched. A second valve, n, enables the pipe K to be completely closed when the motor has to be stopped.

The lamp L is used to heat the vaporiser C_1 when starting and to ignite the gas as it enters at O.

We have already said that the velocity of the gas as it leaves the injector suffices to carry away the amount of air necessary for its combustion. The general rule is to arrange

that the volume of air thus carried away shall be ten times as great as the volume of petroleum vapour. The more air is taken away the lower will be the temperature of the mixture resulting from combustion, so that the motor will not need a water circulation to keep it cool.

The pressure in the chamber *O* and in the pipe is about 120 lbs. per square inch.

The car is also provided with a starting lever for setting the motor in motion.

The car which entered for the Chicago race weighed 704 lbs., and could travel 20 miles an hour on a good road. The motor, similar to the one already described, had four different speeds; its power was 4 effective horse-power, and its total weight 119 lbs. The reservoir *S* held 8 gallons of gasoline.

The Duryea car which ran over the Chicago course only consumed about 3½ gallons of gasoline for a distance of 56 miles, covered in about 9 hours, in spite of the bad state of the roads, which were thickly covered with snow.

The arrangement adopted on the Duryea car is, in our opinion, one of the features and greatest novelties of last year. This generator of compressed hot air is a decided step in a very different direction to that which has hitherto been followed in the construction of gas motors. The idea is absolutely new, and has many practical advantages.

The first of these advantages, and not the least, is that motors with double-acting cylinders, or engines with three cylinders set at 60 degrees to one another, working simultaneously, can be used. This enables the size and weight of a motor for a given power to be considerably reduced, and the motor couple will be much more constant than if Otto-cycle, or even single-cycle, motors, such as are at present employed, were used.

Another advantage is that the pressure in the generator can be varied according to the work to be done by opening more or less the admission valve: the consumption of hydrocarbon is therefore always proportional to the work done.

We are given to understand that a Duryea car will take part in the Paris-Marseilles race, and this will enable us to judge for ourselves of the value of this new auto-car, for in the matter of invention we must never assert anything definitely before we have seen and examined for ourselves. The chief drawback to this American auto-car seems to be the very high temperature of the hot-air reservoir.

THE KANE-PENNINGTON MOTOR.[1]

Maxim has already employed a very light steam motor in America in the course of his experiments in aerial navigation. The motor weighed 330 lbs. per 12 horse-power, but we must add that the exact description of this motor has not yet reached this side of the Atlantic.

Quite recently the technical press announced the invention of a petroleum motor which was a vast improvement upon the above, the inventor having been able to reduce the weight of his motor to 17·6 lbs. per horse-power. The motor in question was the Pennington built by Messrs. Kane, of Chicago, who give the following weights: 29·7 lbs. for a motor of $\frac{3}{4}$-horse-power; 39·6 lbs. for the 2-horse-power motor; 49·5 lbs. for a 4-horse-power motor, or 12·37 lbs. per horse-power. We do not accept the responsibility for the above figures.

However, we must admit that the very simple construction of the motor is characteristic of the American constructor. All has been sacrificed for the sake of lightness: there is no useless part; the stationary parts are used for attachment and the moving parts are used for driving and valve gear.

Petroleum spirit descends from the tank to the engine through a pipe by gravity.

The motor is an Otto-cycle motor; the piston first draws in air with a certain amount of petroleum spirit during part of its stroke. The petroleum vaporises and carburets the

[1] Extract from *La France automobile.*

air, and in so doing cools the cylinder, so that the water-jacket used on similar motors is not needed here.

We shall see farther on that there is another reason for the non-heating of the cylinder.

On its return stroke the piston compresses the mixture of carburetted air at the end of the cylinder.

At the end of the stroke and before the piston starts again an electric spark is produced by a primary battery, and this fires the gas.

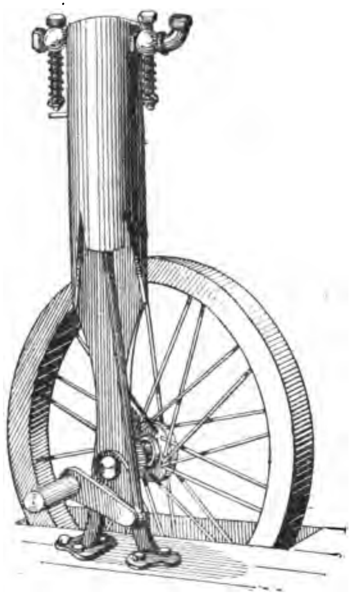


FIG. 73.—The Single-cylinder Kane-Pennington Motor.

The piston is driven forward again, this stroke being the working stroke, and on its return expels the burnt gas.

The air and liquid admission valves are opened by the sucking action of the piston: the exhaust valve, on the contrary, is worked mechanically, and this insures complete expulsion of the burnt gas.

When the piston is drawing in the charge the liquid falls upon a wire which is placed in the upper part of the cylinder. This wire, spiral-shaped, is connected to the primary battery, and assists the complete vaporisation of the petroleum spirit by slightly raising the temperature. No carburator, with its attendant disadvantages, is therefore needed. The $\frac{3}{4}$-horse-power motors have one cylinder, the 2-horse-power two cylinders, and the 4-horse-power four cylinders (Figs. 73, 74, and 75).

The cylinders are strongly made of cast steel. The steel

bottom is screwed to an iron frame and then brazed, this precaution being taken with all screwed parts.

The pistons have three rings. All the parts can be taken to pieces by simply unscrewing a nut.

In addition to the two valves, the motor also has a reducing gearing and a rod working the exhaust valve.

The flywheel is only 20 inches in diameter, and all its weight is utilised at its periphery. The spokes are similar to those used in bicycles. The engine is reversed by simply throwing one of the toothed wheels out of gear.

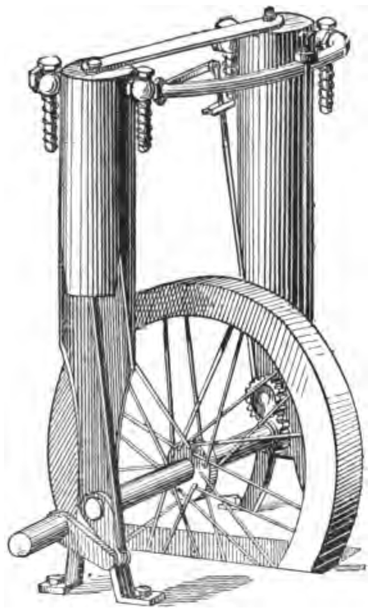


Fig. 74.—The Two-cylinder Kane-Pennington Motor.

The diagrams Nos. 1, 2, 3, and 4, Fig. 76, have been obtained with a motor having a piston 2·46 inches in diameter with a 12-inch stroke. The details and dimensions of this piston are given in millimetres on Fig. 77.

A remarkable feature about this motor is that it works without heating, though no precaution is taken to keep the cylinder cool. Mr. Randol says that he has seen this motor work for hours at speeds often exceeding 1,500 revolutions per minute without any excessive heating of the cylinders, the motor being simply suspended by cords.

The diagrams on Fig. 76 show that the motor works exactly as an ordinary Otto-cycle motor. When the diagrams were taken its average speed was 325 revolutions, but it must be

added that these tests were carried out very roughly. The diagrams enable the indicated power of the motor to be calculated, but the useful work cannot be measured, as the brake used was merely a wooden plank pressed against the motor flywheel.

Diagrams 1 and 2 are valueless, as a leak was afterwards found on a joint of the pipe connecting the indicator to the

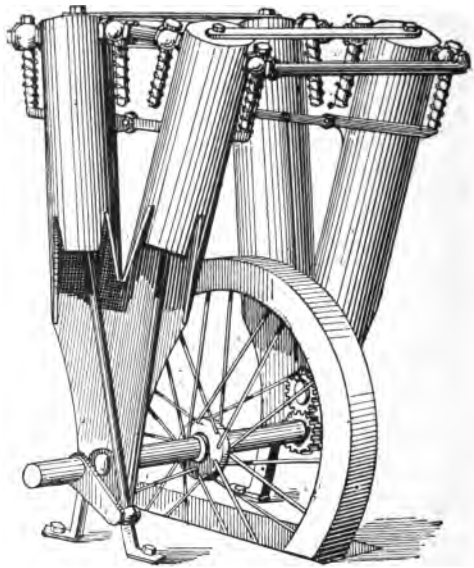


FIG. 75.—The Four-cylinder Kane-Pennington Motor.

cylinder. The only diagrams that can give any useful information regarding the normal working of the motor are 3 and 4. They show that it worked quite regularly, and the diagrams approximate very much to the theoretical cycle of maximum efficiency which can be obtained with an Otto-cycle motor. At the end of the stroke the compression is 64 lbs. per square inch, and increases to 178 lbs. after the charge has been exploded.

The diagrams show, moreover, that deflagration takes place almost simultaneously with the end of the return stroke, and that it is practically instantaneous. This, we know, is one of the essential conditions of a good efficiency. We also notice that expansion is carried far enough to cause the pressure of the gas in the cylinders to fall as nearly as possible to that of the atmosphere.

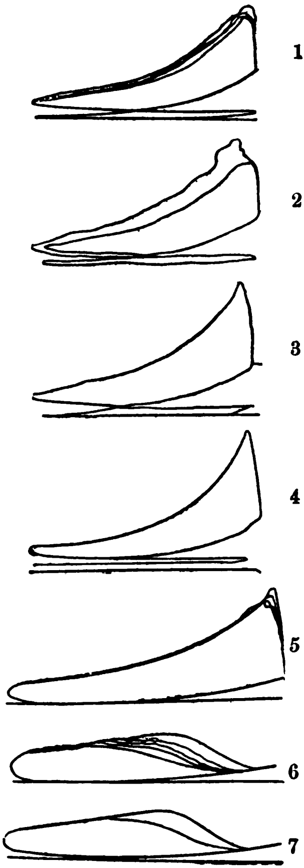


Fig. 76.

Fig. 78 shows the arrangement adopted for vaporising and for firing the gas. This arrangement enables the petroleum spirit to be vaporised inside the cylinder itself, and the non-heating of the cylinder is mainly attributed to this. One pole of a battery is connected with the body of the motor and the other to an *S* spring; the circuit is completed by an isolated wire which leads to the lower nut of the plug shown on the cut. Mr. Randol states that the contact piece, attached to the piston, catches the spring on the return stroke of the piston, which corresponds to compression, and this completes the circuit, the electric current passing through the plug, the spring *S*, and the body of the motor. But as the piston advances the spring *S* slides on *W*, and as the spring is provided with isolators the current is made and

broken alternately a great number of times during the period of compression, which gives rise to a series of sparks which assist vaporisation without firing. At the end of the return stroke the contact piece leaves the spring, and the large spark which results causes explosion.

To tell the truth, it is not easy to understand how this series of small sparks assists the vaporisation of the gasoline without causing explosion at the end of compression, yet the

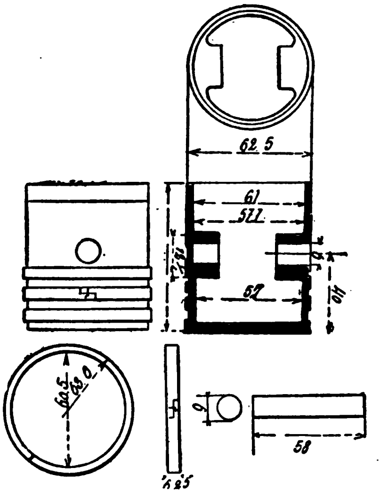


FIG. 77.—Kane-Pennington Motor—Details of Piston.

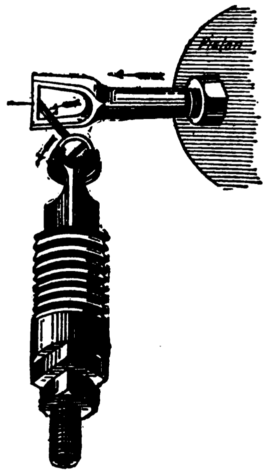


FIG. 78.—Carburator of Kane-Pennington Motor.

diagrams, if they have been obtained with the motor in question, show clearly that from this point of view the motor works marvellously.

We cannot, however, attribute the non-heating of the cylinders entirely to this method of carburetting the air. We will examine farther on the cause which in our opinion explains this peculiar property of the Pennington motor.

We will first state, however, that the diagrams 5, 6, and 7 have been taken from a Regan motor which had a water-jacket

round the cylinder. These motors are arranged to work with a carburator, and as the diagrams in question were obtained by supplying the petroleum spirit direct to the motor they do not give the real value of the motor. These tests were made to determine what effect the Pennington arrangement had in vaporising the petroleum. Diagram No. 5 was obtained on a Regan motor fitted with the apparatus represented on Fig. 78. This diagram is normal, and shows that the explosion was almost instantaneous. This is not the case, however, when the apparatus is done away with; diagrams 6 and 7 show that the temperature of the cylinder is not sufficiently high to cause complete vaporisation, so that explosion takes place during nearly the whole time of the forward stroke.

The series of small sparks in the Pennington motor is one of the causes of the good carburation of the mixture before explosion.

It now remains to be seen why the Pennington motor does not get very heated. Here is one explanation. The motor is built of very thin steel tubes, so that the mass of metal is much less than that of any other existing motor.

Consequently during the first explosion the amount of heat stored in the metal is very slight, and it can nearly all be absorbed before the next explosion by the vaporisation of the petroleum and by contact with the surrounding atmosphere. If, on the contrary, we had a cast-iron motor, and consequently a comparatively heavy one, the amount of heat stored up by the metal would be considerable, and would be only very slightly reduced by contact with air or by the vaporisation of a little gasoline, and a time would come when the temperature of the cylinders would be almost as high as that required to cause explosion. This temperature would remain practically constant during the whole cycle of the motor on account of its heat capacity. Probably with the Pennington motor the same temperature is obtained at the moment of explosion, but it is not maintained, because all the heat stored by the sides

of the motor radiates into the atmosphere or is taken up by the vaporisation of the petroleum. The mean temperature being low, the lubricants used will not vaporise, and the motor will need no water circulation to cool it.

In short, the Kane-Pennington motor can work without a water-jacket on account of the very thin sides of the cylinders and its low heat capacity.

CHAPTER VII

PETROLEUM AUTO-CARS (*continued*)

THE LOYAL MOTOR.

THE motor designed by Mr. Loyal is now being manufactured and supplied to the trade for small works and agricultural purposes. It has not yet been adapted to cars, but its simplicity, its high efficiency, and the absence of a cooling apparatus already show a great progress in motor design for auto-locomotion.

No ignition, no special mechanism for the valves, and yet a single-cycle motor! Such is the surprising result arrived at by Mr. Loyal. Fig. 79 shows the general arrangement.

The cylinder *C* oscillates on two trunnions, one of which admits the gas through a valve, *S*. The exhaust valves at *S′* are four in number, arranged on the periphery of the cylinder. Some patterns of motors, however, have only one valve, equivalent to these four.

The motor sold for light work is $1\frac{1}{2}$-horse-power and 300 revolutions per minute. The flywheel *Y* equalises the motion, and the supply of gas is controlled by a cock *R* connected to a special carburator, described farther on.

Ignition by electric spark has been replaced by a method which we might call 'pneumatic' ignition. By simply compressing the gaseous mixture in a nickle tube the necessary heat for firing is obtained, owing to the well-known principle that for every sudden compression of a gas heat is evolved in proportion to the work done. Before starting the nickle tube is

heated by a small Bunsen burner, but once the motor is started the compression alone is sufficient to cause explosion.

We have already said that it is a single-cycle motor, which at first sight seems incompatible with only one cylinder. But here again principle, or rather a new idea confirmed by experience, has been applied : i.e. 'a burnt gas does not mix easily with a fresh gas.'

Of course, this principle was known, as ignition by incandescent tube is based precisely on the fact that the burnt gas is driven into this tube, and only allows the fresh gas to come into contact with the heated sides of the tube when a certain degree of compression has been attained ; but no one had thought of applying this principle to obtain a single-cycle motor with only one cylinder.

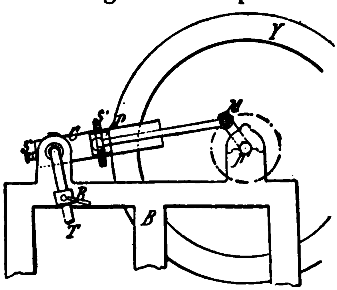


FIG. 79.—Arrangement of Loyal Motor.

The process in working is as follows :

Suppose the motor to be at the period of explosion and the piston thrust forward ; the gas expands during the first part of the stroke till the piston arrives at a certain point in its travel, when the pressure of the gas inside the cylinder falls below atmospheric pressure. From that moment a fresh supply of gas is drawn through the valve S till the piston is at the end of its stroke. On the return stroke the gas is compressed and raises the exhaust valves S', which allow *a certain amount of burnt gas* to escape. The fresh gas had not arrived so far as S'.

Compression will continue when the piston has passed the exhaust valves, but the gas remaining in the cylinder can no longer escape, and the degree of compression at the end of the stroke will be sufficient to cause the explosion of the fresh gas

in the upper part of the cylinder. The cycle is then repeated in the above order.

We said that all the burnt gas was not expelled; this is perhaps one of the causes which prevents the motor from heating, although nothing is done to cool it.

To make matters more clear, let Q be the heat evolved per explosion, ν_1 the volume of fresh gas, and ν_2 that of burnt gas. If the latter had been expelled the temperature of the gas at the time of explosion would have risen to

$$T_1 = \frac{Q}{c\nu_1},$$

c being an experimental coefficient practically proportional to the specific heat of the gaseous mixture.

In the case of a volume ν_2 of neutral gas the temperature would become

$$T_2 = \frac{Q}{c(\nu_1 + \nu_2)},$$

and it is easy to see that T_2 will vary inversely with ν_2. Assume, for instance, $\nu_1 = \nu_2$, we shall find that $T_2 = \frac{T_1}{2}$; the temperature would therefore be halved.

Of course, the pressure due to explosion also falls in the same proportion, but the work that can be done by the gas is not affected, because expansion can be carried much farther, owing to the great volume of gas. In point of fact, an appreciable saving is realised, as all the *available* heat is utilised to produce work instead of heating the circulating water, as in ordinary motors. Mr. Loyal states that this saving amounts to 30 per cent., so that, instead of consuming 0·11 gallon of petroleum per horse-power per hour, not more than 0·055 gallon is required. This statement agrees with theory, as 50 per cent. of the total heat is absorbed by the circulating water in ordinary motors.

Before concluding the description of this interesting motor

we will say a few words concerning Mr. Loyal's new patent automatic carburator, shown on Fig. 80. The apparatus consists of a reservoir *R* divided into two compartments *C* and *C'*, the former of which holds the gasoline.

A spindle, *t*, provided with a spring at its lower end, passes through the lower compartment *C'* and prevents the petroleum from falling into it when it does not revolve. When, however, the motor is drawing in the gas the wheel of the spindle revolves and petroleum falls, drop by drop, at a rate which is always proportional to the velocity of rotation of this wheel, which is revolved by the suction of the motor itself, as air is drawn through *O'* and into *C'*, causing the screw *H* to revolve with the spindle *t*. The petroleum then falls upon the screw, and the combined action of the air and screw vaporise the petroleum thoroughly, and thus carburet the air before it passes through the pipe, *T*, which leads to the explosion chamber of the motor. The higher the speed of the motor the more air will it draw in, mixed with an unvarying proportion of petroleum vapour, as the supply of petroleum depends upon and is proportional to the speed of rotation of *t*—that is, to the amount of air drawn in.

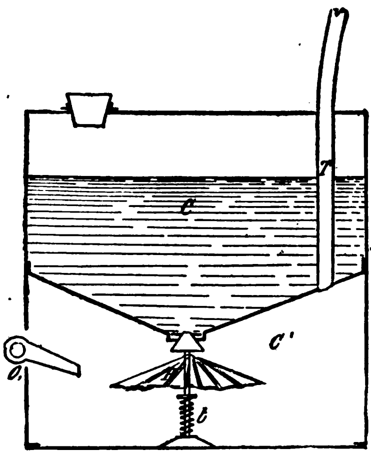


Fig. 80.—The Loyal Carburator.

Consequently the carburator is automatic in action and supplies a constant charge of air and carburetted vapours mixed in unvarying proportion. Heavier petroleum oils can be employed with this motor than with others, and with motors for

agricultural purposes Mr. Loyal uses *any* mineral oils that can be procured. These advantages of economy and simplicity are a real progress in motor building.

This motor can also be adapted to pleasure launches.

THE DAWSON MOTOR.

Shown on Fig. 81, this motor can be equally applied for traffic along roads, although primarily designed for stationary plant. This motor has no valves, and explosion is obtained by means of an incandescent tube. A barrel closed at its lower end forms the piston *P*, and is propelled by the connecting rods *B* and *C*. The rod *C* is connected to the piston by a universal joint, and at its other extremity is provided with a worm wheel *D*, which engages with a worm formed on a disc keyed to the crank. This arrangement enables the rod *C* to rotate the piston *P*. The latter has two apertures, *a*, on the same diameter, and the cylinder has similar openings for admission and exhaust of gas. The combined movement of translation and rotation of the piston is so arranged that gas is admitted through *a* during a part of the

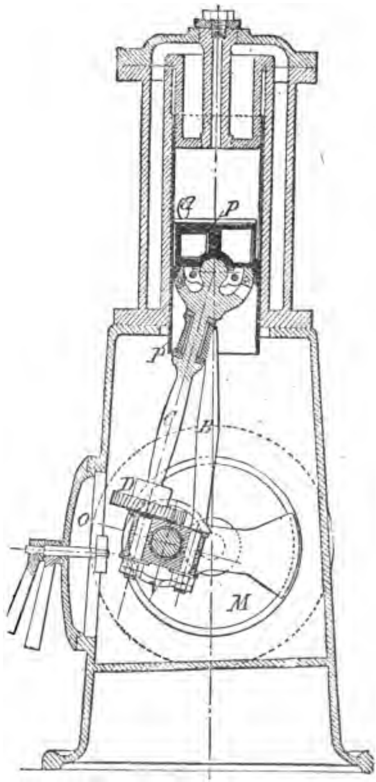


FIG. 81.—The Dawson Motor.

forward stroke of the piston. The holes *a* are closed on the return stroke till the end of compression, at which moment one of these holes *a* comes opposite an incandescent tube and explosion takes place. As the piston again revolves upon itself *a* comes opposite the hole forming the exhaust port of the gas.

Such is the principle of the Dawson motor, which, in our opinion, leaves much to be desired. The holes in the cylinder must be comparatively long and spiral-shaped to coincide with the position of *a* in order that gas may be admitted and expelled during the greater portion of the stroke. The piston, in short, becomes a circular slide valve, and, as it is impossible to adjust when worn, we do not see how leaks can be avoided between the cylinder and the exhaust. Besides, the large area of the piston causes much friction, which must affect the efficiency of the motor.

This motor, like most petroleum motors, is provided with a water-jacket.

THE LEPAPE PETROLEUM TRACTOR.

Mr. Lepape's solution of the problem of road locomotion is to employ a tractor for hauling any kind of car.

Pleasure locomotion, however, is hardly compatible with such ugly, noisy, and heavy iron or steel horses. We have already pointed out, when dealing with steam tractors, that they were only suitable for industrial purposes such as goods transport, rural buses, or haulage of heavy vans. Does, however, a petroleum tractor offer any advantages over a steam one? We think not, as it necessarily works less regularly, is much noisier, and the absence of boiler and resulting saving in weight is not an advantage, but rather the reverse, as it reduces the adhesion of the wheels, and thereby the weight that can be hauled.

This motor and its machinery are, however, exceedingly interesting, and might certainly be applied with success to trams or buses.

The motor has three cylinders, set at 120 degrees to one another, so as to equalise the motor couple and reduce the vibrations due to the reciprocating parts. We regret not being able to describe the parts in detail, as Mr. Lepape was unwilling to supply the necessary information. We may say, however, that the charge is admitted and expelled through valves as with most petroleum motors, and that ignition is obtained electrically.

The arrangement of the three cylinders is well designed,

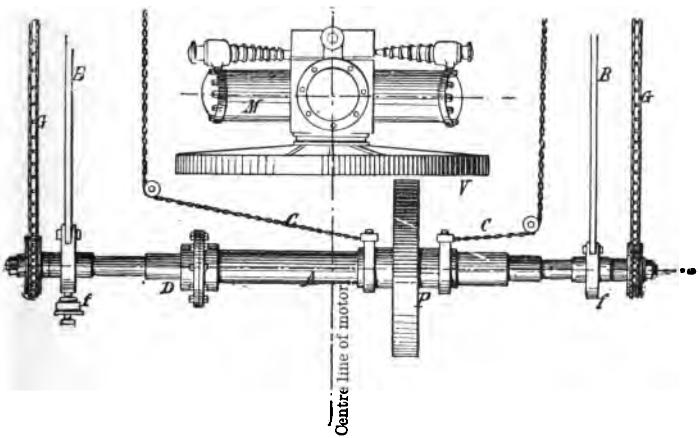


FIG. 82.—The Lepape Transmission Gear.

and is advantageous for traction. Mr. Lepape's system of power transmission is also worthy of mention, and is shown on Figs. 82 and 83.

The movement is transmitted from the motor to a differential shaft by means of two discs, *P* and *V*, which form a friction coupling, and are employed for throwing in or out of gear, for change of speed or for reversing, no other device being required.

The disc *V*, which is of cast iron, is keyed to the motor shaft, and acts as a flywheel as well. The disc *P* is set upon

the differential shaft so that it can move up and down this shaft and come into contact with *V* when required. This enables any speed from zero to maximum to be obtained by shifting the disc *P* along the diameter of *V*. The maximum speed will be attained as *P* engages with a point on the circumference of *V*, and this speed will decrease as *P* approaches the centre of *V*, a reverse motion being obtained as *P* passes to the other side of the centre of the disc *V*.

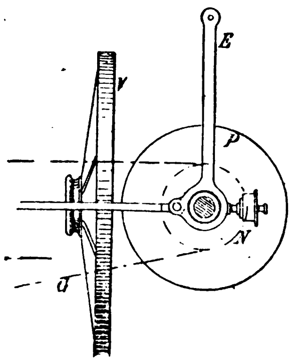


Fig. 83.—The Lepape Transmission Gear.

The differential shaft has two pinions, which drive the car wheels by means of the Gall chains *G*. The differential arrangement enables these pinions, and thereby the wheels, to move independently when passing round curves.

We may point out that the tension on the chains increases with the tractive power, so that adhesion between the friction discs *P* and *V* is proportional to the power required to be transmitted; the driver need only bring the two discs into contact, and the necessary pressure will be obtained automatically.

The driver has two levers within reach—one at his right for throwing the motor in or out of gear, the other for steering the rear wheels, which are mounted on pivots.

THE TENTING CAR.

Fig. 84 is a general view of this car, and Fig. 85 a plan of the gear.

A Tenting motor is used; it is a horizontal Otto-cycle motor, has two cylinders, a limited speed of 250 revolutions per minute, and can provide 4 horse-power.

Valves control the admission and expulsion of the charge,

and the general arrangement of the motor is similar to others already described. The valves are placed horizontally, and this seems to us a bad arrangement unless they are properly guided. The motor revolves slowly, is fairly bulky, and is not always easy to start. The lever *G* shown on the cut steers the front wheels, which are pivoted, by means of two

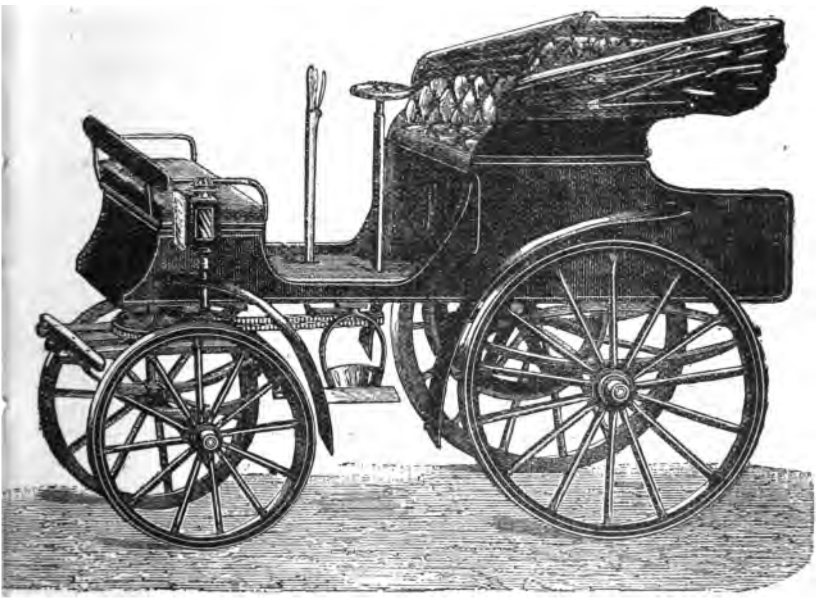


FIG. 84.—The Tenting Car.

rods. The general view (Fig. 84) shows an alternate method of steering, a chain being substituted for the lever *G*.

Although Mr. Tenting has gone back to ignition by incandescent tube, after having tried electricity, we think his electric apparatus cannot have been properly arranged, or it would have given at least as good results as incandescent firing. The cylinders are kept cool by a water-jacket.

The arrangement for reversing and for varying the speed is a great feature of Mr. Tenting's car. This is shown at *D* and *E*, and somewhat resembles the method adopted in the Lepape tractor already described. Friction is employed for transmitting the power from the motor to the pinions which revolve the driving wheels by a Gall chain. Unlike the Lepape system, the discs *E* and *D* are constantly in contact together under a constant pressure. At starting, the disc *E*, which slides along a shaft, is at the centre of the discs

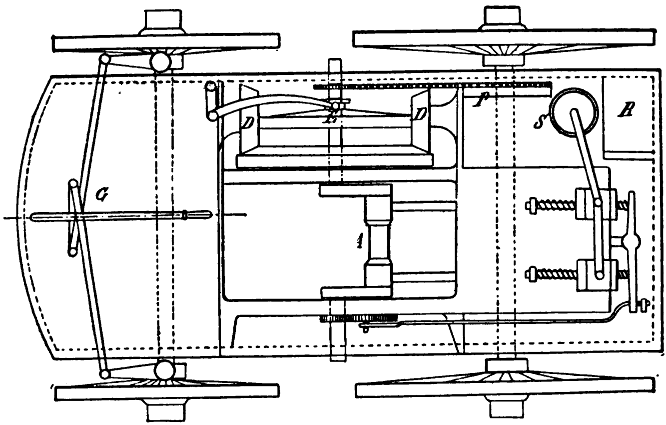


FIG. 85.—Machinery of the Tenting Car.

D, but once the motor has started the car can be run forward or backward by simply shifting *E* to the right or left of its midway position. The speed of the car, compared to that of the motor, will be greater as the distance of *E* from the centre of *D* increases.

Mr. Tenting's system is not bad theoretically, but it remains to be seen how it works in practice. No attempt has been made to dispense with the chain, and yet this is one of the very improvements that should be sought. At first sight there is nothing to prevent the shaft *E* being made to work the drivers by dif-

ferential gearing, and with suitable diameters for E and D the required reduction of speed could be obtained. Mr. Grélet tells us he intends to try this system of transmission. We think the trial is worth the while, because, if successful, he will have greatly improved and simplified the driving gear of auto-cars.

THE DELAHAYE CAR.

The Delahaye car, on view at the Champ de Mars exhibition, was completed too late to take part in the Paris-Bordeaux race.

Fig. 86 shows the car in question, which is elegant in

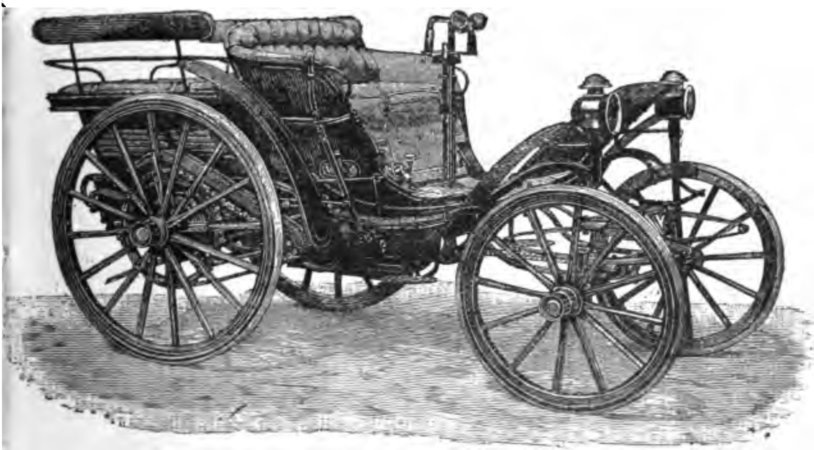


Fig. 86.—The Delahaye Car.

appearance. The wheel base is large, that is to say, the axles are far apart, and the forepart of the car is slender and has less the appearance of an ordinary horse carriage adapted to a novel use than is generally the case with auto-cars.

The car frame is of steel tubes ; consequently it is lighter for the same resistance than an ordinary carriage. The car body fits on to this framework, and can be converted from a

brake with six seats into a phaeton with four seats, or *vice versâ.*

The car is steered, like the majority of those we have described, on the divided-axle principle, and, owing to the light weight on the fore-axle, steering should be gentle and easy.

The motor used on the Delahaye car is its most interesting feature. It has two balanced cylinders, that is, the pistons work cranks set at 180 degrees to one another.

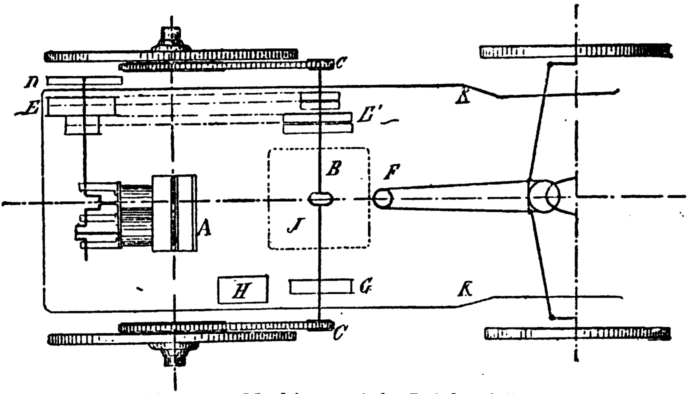


Fig. 87.—Machinery of the Delahaye Car.

Will this arrangement, however, prevent all vibration? We have already dwelt upon the advantage of this arrangement, and certainly if the parts of each piston are of equal weight the pulsations of the motor when full working will hardly be felt.

This will not be the case at moderate speeds, as part of the jerks felt on an auto-car are not due to the reciprocating motion, but to the *shock* produced by explosion. On firing the gas the cylinder has a tendency to go in one direction and the piston, crank, and shaft in another. The framework supporting the motor is consequently subjected to a sudden stress, which ceases almost immediately afterwards.

These stresses, although short in duration, take place every revolution, or every other revolution, and cause the annoying vibration that we feel on petroleum auto-cars. These pulsations become less as the motor revolves more quickly, and may even cease altogether if the motor is provided with a flywheel sufficiently powerful to store up the energy of each explosion.

The arrangement on Fig. 87 shows the machinery of this car. Belts are used for the power transmission, and two different speeds may be obtained. These belts work on a differential shaft, *B*, which, by means of pinions *C* and two Gall chains, transmit the power to the rubber-tyred driving wheels. The brake is fitted to a pulley, *G*, keyed to the shaft *B*, and a wheel *D* is used to start the motor.

The normal speed is 450 revolutions per minute, and it has 5 effective horse-power. Mr. Delahaye prefers electric firing, as he is thus enabled to vary the ignition point of the charge.

A small centrifugal pump causes water to circulate around the cylinders and in a set of tubes arranged in the forepart of the car, so that the water may be cooled before passing back into the water-jacket of the motor.

In conclusion, we may state that the Delahaye cars are exceedingly well spoken of ; the motor employed is a French invention and of French manufacture, and will probably compete successfully with the Daimler motor which won the Paris-Bordeaux race.

THE ROSSEL CAR.

We regret we are unable to give a complete description of Mr. Rossel's car ; its careful workmanship and arrangement entitle it to a foremost place amongst auto-cars.

The steering and starting levers are well within reach of the driver, and their arrangement facilitates the driving.

The car can pass round sharp curves, and can run backwards ; it can be stopped rapidly by means of two powerful brakes, one of which is sufficient to skid the wheels. Speeds

from 3 to $12\frac{1}{2}$ miles an hour can be obtained, and banks of 1 in 10 can be climbed.

The car frame is of steel tubes, and is carried by means of very soft suspension springs on four metal wheels with tangent spokes and rubber tyres.

The Daimler motor, the driving gear, and the car body are all attached to this framework.

The car carries a supply of 6·6 gallons of petroleum, which is sufficient for a run of 124 to 155 miles, and a supply of 11 gallons of water necessary for cooling the motor cylinders.

An additional supply of a few pints of water is required every 30 miles.

The wheels and the main parts of the machinery all work on ball bearings, which avoids lubrication along the road.

THE PYGMÉE MOTOR.

We think that the Pygmée motor, which is a French invention and built by a French firm, will become an exceedingly dangerous rival to the famous Daimler motor.

As its name implies, it is small and not cumbersome, but its slight bulk is entirely due to the arrangement of its parts, and not to a reduction in size of the latter. The Pygmée motor is strong and easy to manage, so that it will be much appreciated by those who use it.

Fig. 88 shows a vertical 4-horse-power motor; those supplied to cars are horizontal, but otherwise similar in all respects.

The Pygmée motors are all balanced; that is, they have two cylinders whose pistons work cranks set at 180 degrees.

We have already dwelt upon the advantage of this arrangement, which avoids vibration due to the alternating motion of the parts.

As usual, the admission valves are opened by the suction of the motor, and the exhaust valves, inclosed in the box *E*,

are worked by cams keyed to an intermediate shaft, *I*, which revolves at half the speed of the main shaft.

Speed is regulated in quite a special manner, and any speed may be obtained.

The rod *t* is connected to a regulator working centrifugally and carried by the flywheel; as the motor revolves the fly-

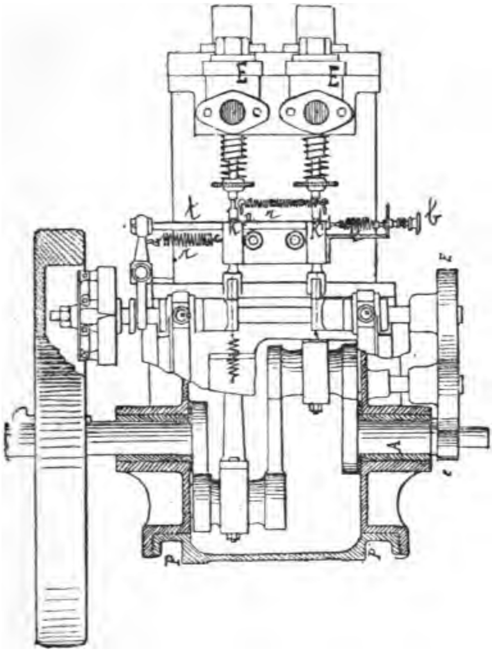


Fig. 88.—The Pygmée Motor.

wheel tends to push the rod *t* from right to left. This action is counterbalanced by a spring, *r*, whose tension can be varied by means of a screw, *b*. If the motor revolves too quickly the tension of the spring is overcome, and the rod is pushed towards the left against the ridge *K*, which worked the exhaust valve of the left cylinder.

As exhaust cannot then take place at that moment, the piston will not draw in a fresh charge of gas on the following stroke, and explosion will not take place till the motor is brought back to its regulation speed, which is determined by the tension of the spring *r*.

If the motor, now working with one cylinder, were still to revolve too quickly, the rod *t* would go still farther towards the left, and would push *K′*, thus preventing the second cylinder from doing any work.

The motor can work either with petroleum or with spirit, on account of its special carburator. The latter simply consists of a spiral tube which surrounds the burners for igniting. When the motor draws in the charge the petroleum or spirit, by means of a jet of air, passes into the spiral tube, and vaporises before entering the cylinders. The mixture thus obtained is too rich to be inflammable. When petroleum is used the spiral tube is inside the burner, whilst it is outside when spirit is employed instead.

The air and carburetted vapour admission ports are arranged so as to cause a whirl of gas before going into the cylinder ; this gives a homogeneous mixture, and avoids failure of firing on account of the mixture being either too rich or too poor when it comes into contact with the incandescent tube during compression.

In conclusion, we will add that, owing to a high compression of 57 lbs., the consumption of spirit or petroleum does not exceed 0·968 lbs. per horse-power per hour. When working with gas the motor burns about 24·7 cubic feet per horse-power per hour.

THE GNOME GAS AND PETROLEUM MOTOR.

Amongst new motors we may call particular attention to that built by Mr. Louis Séguin. The Gnome—such is the name which Mr. Seck, the inventor, has given it—is strongly built, and all its parts are so simple that it is an exceedingly

practical apparatus, and can be confided to comparatively inexperienced people. It works very regularly, and can therefore be applied to electric lighting, although it has only one cylinder and its speed is always under 400 revolutions per minute.

The Gnome will certainly have considerable success for

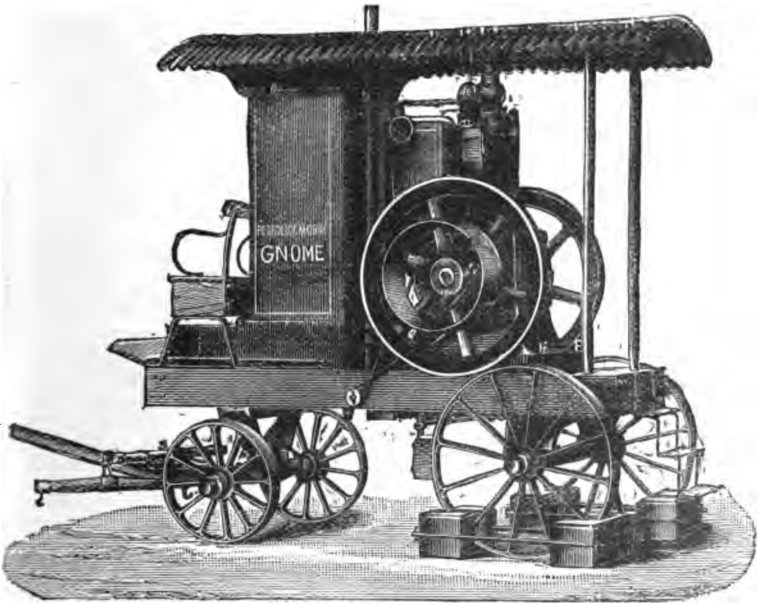


Fig. 89.—The Gnome Auto-Car.

industrial purposes, but if we describe it in this book it is because it can also be applied to auto-cars and locomotives.

Fig. 89 shows the Gnome placed on a car for agricultural purposes. It will be largely used in this direction, and soon supersede steam cars, which are so difficult to handle.

A petroleum locomotive designed for contractors and farmers is shown on Fig. 90. We think that petroleum loco-

motives are very suitable for unimportant and short runs; they are light, and do not require heavy or well-built permanent way. The motor can also be used for any other purpose if required. Fig. 91 shows a general view of the Gnome, and Figs. 92 and 93 are two sections which show its construction.

The frame *A*, containing oil at the bottom, is joined to the cylinder *C* and to the bearings. The latter are lubricated by two rings carried by the shaft which dip into the oil.

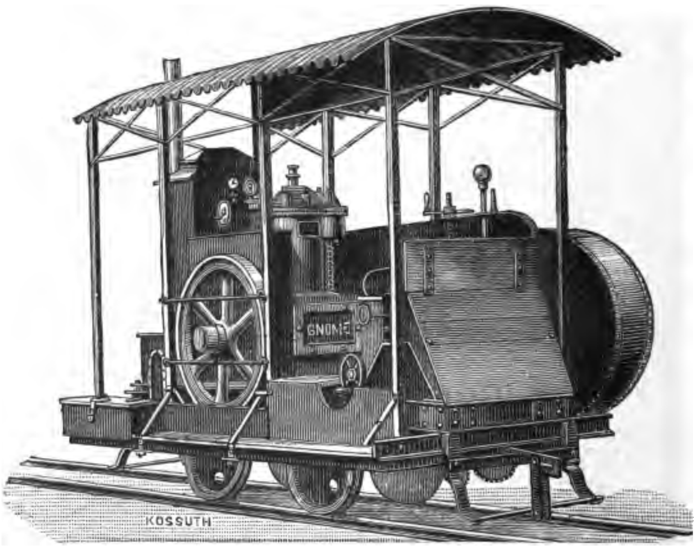


Fig. 90.—The Gnome Locomotive.

The cylinder and moving parts are lubricated by the oil being projected by the head of the connecting rod as it dips into the oil.

The cylinders are cooled in the usual way by means of a water-jacket.

The exhaust valve *E* is opened mechanically by a horizontal slide valve worked to and fro by an eccentric *X* and an endless

screw. This is the first time we have seen this arrangement adopted, and it is much simpler than the ordinary method of reducing gearing by means of two toothed wheels, one of which is on an intermediate shaft revolving at half the speed of the main shaft.

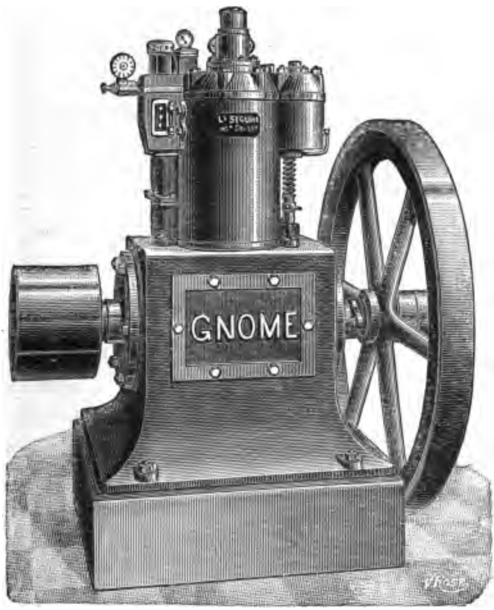


FIG. 91.—The Gnome Motor.

The charge is admitted during the first forward stroke through the valve *M* and pipe *P*.

Before arriving in the motor the petroleum passes through a gasifier heated by a burner, *G*. When the motor is drawing in the charge a small orifice, *P*, allows a certain amount of air to pass in, which draws in petroleum: the latter vaporises in the gasifier and forms, with the air drawn in, a mixture which is too rich to be inflammable.

The petroleum vapour then passes into the motor, where it meets at right angles the air necessary for its combustion, and this stirs the gas up thoroughly and produces a homogeneous mixture.

The composition of the explosive charge may be varied by controlling the supply of petroleum vapour.

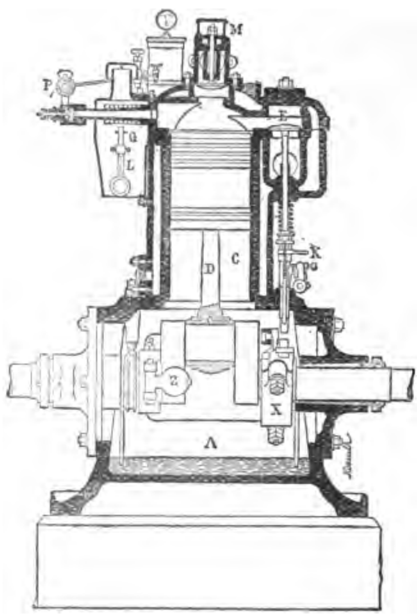


FIG. 92.—Section of the Gnome Motor.

The petroleum is sent from the main reservoir *b* to *a* by means of a small pump worked by the eccentric *X*. A constant level is maintained in *b* by means of an overflow. This is essential if the motor is to work well.

We may also call attention to the method of regulation adopted, which is different to those previously described.

In most motors the exhaust valve is prevented from opening when the normal speed is exceeded. This causes the burnt gas to be compressed and expanded again before a fresh charge is introduced for explosion at the end of compression. The same result can be obtained by preventing the exhaust valve *E* from falling on its seat when the motor revolves too quickly. In order to do this the centrifugal regulator *Z* bears upon a catch *K* so as to bring it towards the left and thus prevent the valve *E* from falling on its seat.

Consequently during the next stroke the motor draws in the exhaust gas through the valve *E*, then drives it back, and continues to do this until the motor has returned to its normal speed, when the catch *K* will no longer prevent the valve from closing.

This method of regulation has given such good and practical results that it has been applied to electric lighting, and we know that in such an application any variation of speed exceeding 2 per cent. would have rendered the method impracticable.

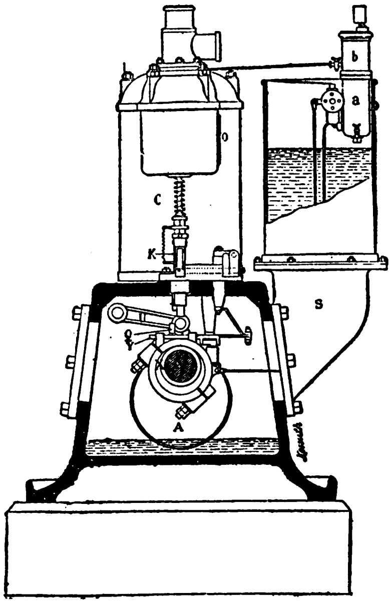


Fig. 93.—Section of the Gnome Motor.

In conclusion, we may say that the Gnome well deserves its budding reputation, and offers the best guarantee for regular and economical working. We consider it extremely applicable to small locomotives where a certain weight is necessary for adhesion, but we do not think that it can be applied to pleasure auto-cars unless Mr. Séguin can design a much lighter pattern for this purpose.

We hear that Mr. Séguin is now building a special type of conjugate motor for pleasure launches.

CHAPTER VIII

ELECTRIC AUTO-CARS

THE JEANTAUD CAR

MR. JEANTAUD is the author of an exceedingly well-designed electric car which entered for the Paris-Bordeaux race. The car covered half the course, about 370 miles, but at what a sacrifice! Notwithstanding relays about every fifteen miles along the road, the car arrived far behind all the petroleum cars.

We do not mean to infer by this that electric traction is a utopia, but that it should only be resorted to in special cases such as we have described in Chapter III.

The Paris-Bordeaux test therefore only proves one thing, namely, that Mr. Jeantaud can build an electric car.

The car has a box seat in front seating two, and two seats behind placed back to back (Fig. 94). The wheels are of hickory wood, those in front being 3′ 3″ in diameter and the rear ones 4′ 7″. The load is distributed on front and rear wheels in proportion to their radii. The fore-carriage has two pivots, so that steering is gentle and reliable; it is specially designed so that all its parts only work in tension.

Two straight springs joined together at the centre rest on the cross-bearer near the pivots, and are placed across the underside of the car-body which they support (Fig. 95).

This arrangement gives great flexibility to the car, and diminishes the pull, as when one of the wheels rides over a stone, for instance, it does not need to lift the whole car over the obstacle, as the car-frame oscillates around the central

point of attachment of the springs, and consequently no sudden jolt is felt.

The car framework is made of weld steel. The journals of the front axles are 1·77 inch in diameter, and those of the rear axles 2·16 inches. On starting from Paris an accident occurred, the rear axle being strained, and this involved stopping

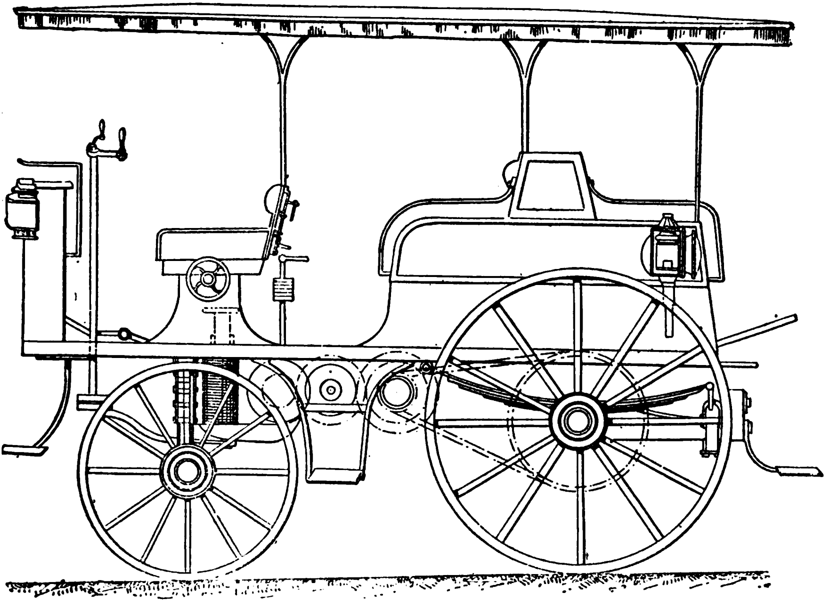


FIG. 94.—The Jeantaud Car.

every hour to cool and oil the heated bearing. On arrival at the winning post the journal was found to work so stiffly that the delay of the electric car in reaching destination is attributed to this cause.

The brake gear consists of an instantaneous brake, worked by a pedal near the conductor, which breaks the circuit; of a graduating brake worked by two wheels placed at either

end of the driver's box, and of an appliance which stops the car if the chains should break on an incline.

The machinery consists of the shaft carrying the differential gear and driving the wheels by means of two pitch chains.

The differential has two bevel wheels, which enable speeds of 7½ and 15 miles to be obtained in excess of the normal speed of the motor.

The motor was designed and built by Mr. Rechniewski,

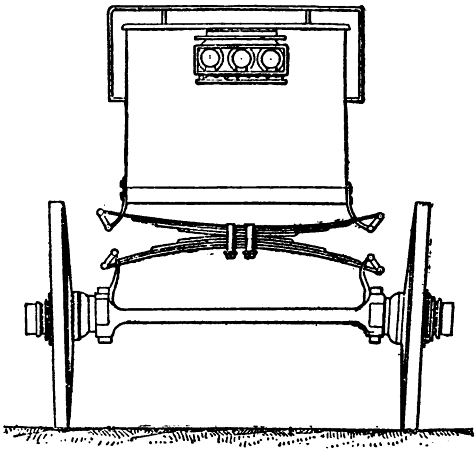


Fig. 95.—Springs of the Jeantaud Car.

engineer of the Postel-Vinay Co., and its efficiency sometimes exceeds 90 per cent., as shown by the following table :—

Power		Commercial efficiency
Couples	Horse-power	
1	2·4	0·68
2	4·6	0·89
3	6·5	0·92
4	8·0	0·91
5	6·3	0·90
6	10·4	0·99

The motor was built to supply about 6 horse-power, the power required for a speed of 15 miles an hour under ordinary working, at a tension of 70 volts with 70 ampères of current. Although its weight of 550 lbs. is comparatively low, this motor can exert sudden pulls when required, and give twice the power for which it has been designed.

The accumulators supplying the motor consist of 38 elements (type C 21, Fulmen Co.) arranged in twelve boxes containing three and four compartments. Each element, weighing 33 lbs., has a capacity of 300 ampère-hours for 10 hours at an ordinary discharge rate.

For a discharge of 70 ampères of current, corresponding to about 2·27 ampères per lb. of plates, the battery still has a minimum capacity of 210 ampère-hours, so that it can drive the car at 15 miles an hour for 3 hours on a good and level road. The supply of 70 ampères has often been exceeded, and in some cases doubled. The accumulators have sometimes supplied 200 ampères during an appreciable time without lowering the electromotive force permanently.

Each battery, weighing 1,870 lbs., will run for about 25 miles on a good road. In the Paris-Bordeaux race the accumulators were charged at stations along the road, the process taking about 10 minutes.

To sum up, we find that with 1,870 lbs. of accumulators, 570 lbs. of motor, and 220 lbs. of fittings, we arrive at a total weight of 2,660 lbs. for conveying 924 lbs. of passengers a distance of 25 or 30 miles. Comment is needless, and the above figures demonstrate that it is impossible to get an economical electric car when over 20 miles has to be travelled at one stretch, as the dead load carried greatly exceeds the weight of passengers carried and weight of car.

MESSRS. MORRIS & SALOM'S ELECTRIC AUTO-CAR.

Although it did not perform the whole distance in the 'Times Herald' race at Chicago, an electric car, the 'Electro-

bat,' belonging to Messrs. Morris & Salom, won the gold medal.

This again shows that the first to arrive are not necessarily prize winners, as, for instance, Messrs. de Dion and Bouton in 1894, and Mr. Levassor in 1895, because they are disqualified on the grounds of non-compliance with the conditions drawn up for the race.

The Chicago jury, no doubt mainly consisting of electricians, awarded the first prize to the No. 2 Electrobat, because the car was clean and easy to drive, and there was neither noise, smell, heat, nor vibration, and, in short, because it was an exceptionally well-built car.

For this reason we think it will be interesting to give a description, taken from a letter by the makers, of the car.

Messrs. Morris & Salom began their investigation of electric traction as applied to auto-cars in June 1894. Their first car was specially designed for traffic in the streets of Chicago, and they endeavoured to build a car capable of daily working on ordinary roads, and not one which would require an ideal road. For this reason they sacrificed certain conditions of weight, general arrangement, and size of motor which ordinary auto-car builders consider so essential.

Their first car was ready by August 1894, and since that date has been in daily working, excepting during the winter months, without any serious hitch. They have never yet been obliged to haul the car home by animal traction. The car weighs 4,250 lbs. without passengers. The accumulators weigh 1,600 lbs. The car will run from 50 to 100 miles, according to the profile of the road, without recharging; the maximum speed is 15 miles an hour. There are 60 accumulators, each of 100 ampère-hours capacity.

The electrical capacity of the battery is 13 hours at maximum discharge rate. The motor, built by the General Electric Company, is a 3-normal-horse-power type, weighs 300 lbs., and can develop 9 horse-power during a short time.

The driving shaft works, by means of a pinion, an intermediate shaft, which drives the rear wheels by means of a balance gear, and enables the wheels to move independently when turning a corner.

No. 2 Electrobat, which took part in the 'Times Herald' race, was built to carry four passengers, including the driver. It weighs 1,650 lbs., and its elegant appearance is an excellent model to follow in designing new cars. All the machinery is hidden except the steering lever, so that it is not open to the reproach of looking more like a locomotive than a pleasure car. Two 'Lundell' motors of 1½ horse-power each are used, and are placed in the forepart of the car; they work the driving wheels by means of a pinion. The steering is effected by means of the lever already mentioned, which acts on the rear wheels.

Messrs. Morris & Salom encountered opposition from car-builders on several points. The general opinion, for instance, seemed to be that it was preferable to have a movable fore-carriage and a fixed rear-carriage. Practical results have demonstrated, however, that Messrs. Morris & Salom were not far wrong, as the car steers very easily and can turn in a circle of 20-feet diameter. Ordinary wooden wheels are used with pneumatic tyres, which until now appear to have given every satisfaction.

The battery was supplied by the 'Electric Storage Battery Company' of Philadelphia. It has four groups of twelve accumulators, with a capacity of 50 ampère-hours per accumulator. They are conveniently arranged in boxes, and can be taken out and replaced in less than two minutes. They are provided with automatic contacts, and will give three different speeds and reverse. A maximum speed of 20 miles an hour can be attained on good roads, and 25 to 30 miles can be run without recharging.

Each 50 ampère-hour accumulator weighs about 13 lbs. complete. Twelve arranged together represent a maximum

discharge rate of 1 kilowatt-hour or $1\frac{1}{3}$ horse-power-hour. The weight of such a battery is about 160 lbs., and it can therefore be easily handled by two men.

We quote Messrs. Morris & Salom :—

'We believe that the most practical application to which these vehicles might be put at the present time is for service in parks and delivery waggons. We do not consider it practicable at the present time to send out such vehicles broadcast over the country before any proper arrangements have been made for their intelligent care and maintenance. We think that the proper plan for their introduction is to construct a sufficient number of vehicles of one kind as to warrant the building of a charging station, where the batteries can be charged and the vehicles kept when not in use. This will enable a systematic and intelligent inspection of the various parts of the machines, and will prevent all the troubles that would naturally arise from inexperienced persons handling and operating the same.

'While we have made no close estimate as to the cost of manufacturing in quantity, we believe that ordinary delivery waggons can be constructed for from $600 to $800 and pleasure carriages from $1,200 to $1,500.

'The magnitude of the business and the possibilities which it may assume in the future can be best considered by comparing the work now done by horses with that which could be accomplished by motor vehicles. At the present time there are probably no less than 100,000 horses in Philadelphia. It costs to keep these horses, on an average, including feeding, shoeing, harness, and depreciation, or life of the horse, not less than $1 per day, or, in round numbers, about $30,000,000 a year. The work they do could be accomplished by motor vehicles at an expense not exceeding fifty cents a day, or about $15,000,000 a year, thus making a net saving for this city alone of 50 per cent. over animal traction.'

These figures appear somewhat exaggerated, and we do not

see how a capacity of 50 ampère-hours can be obtained at maximum discharge rate with a total weight of 13 lbs. Of course it is possible to get accumulators to fulfil these conditions, but would they be sufficiently strong to long resist the hard and irregular work they are called upon to perform?

The electric car has certainly more *raison d'être* in the United States than in Europe. On the old continent it would often be impossible to re-charge the accumulators, say every twenty miles, which is not the case in America. Electric power is cheap there on account of its extensive use, and there is nothing surprising in the statement that electric traction would be cheaper than horses in Philadelphia, whereas in France, for instance, counting the price at 10*d.* per kilowatt-hour, the reverse would probably be the case.

Electric traction by accumulators is expensive, chiefly on account of their heavy weight. For instance, for a 25-mile journey, No. 2 Electrobat has 634 lbs. of accumulators, 300 lbs. of motor, and about 144 lbs. of gearing and regulator to haul, making a total dead load of about 1,100 lbs., which is very heavy for a 1,650 lb. car for four passengers. Twice as much pull is required, therefore, as would be necessary for hauling the car and passengers without the electric parts.

The greater the distance travelled the more accumulators will be required, thus increasing the dead load, and though this method of traction may be cheap up to a certain distance, it will entirely depend, as Mr. Salom has pointed out, upon having central charging stations near at hand.

We think, therefore, that notwithstanding the success of electricity in the 'Times Herald' race, it will have all its work cut out to compete against petroleum.

THE BOGARD ELECTRIC CAR.

This car is shown on Fig. 96. This pattern of car is well suited to traction by accumulators, because there is plenty of space available for storing the latter. Mr. Bogard has not

designed his car for high speeds; he has sought rather to obtain a practical electric car for running in towns at a speed of $7\frac{1}{2}$ miles an hour for 10 hours at a stretch. This is the most successful attempt that has yet been made in this direction, and, if economy is not considered, we think Mr. Bogard's car fulfils all the primary practical conditions. The car can run for a whole day, and that is a great point for

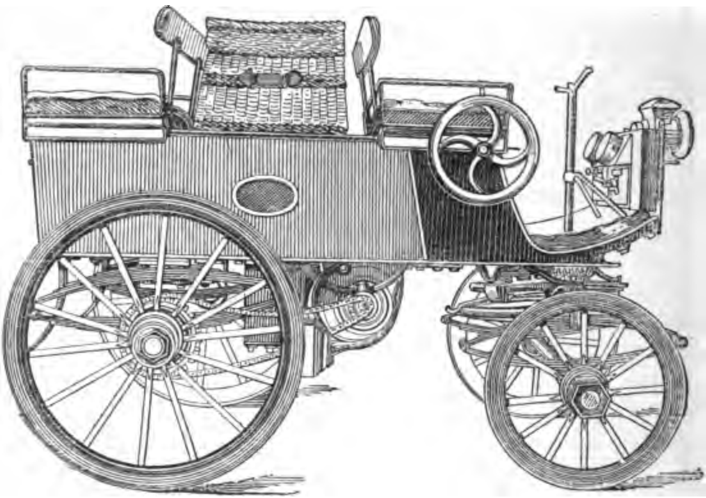


FIG. 96.—The Bogard Car.

anyone who wishes to go a long distance. It is made to carry five passengers, but six can be taken if required.

Dujardin accumulators are employed; they are stored in the body of the car, and consist of 51 elements (light pattern), each made up of 3 positive and 4 negative plates, inclosed in hardened guttapercha boxes, which are strengthened by a metal plate embedded in the thickness of the rubber sides. The three positive plates are connected together, so as to be easily taken out for examination. Each of these elements weighs 49·5 lbs., including cover and connections, and its

capacity is 300 ampère-hours, so that the whole battery has a total energy of 30 kilowatt-hours, which suffices for 10 hours' working at average speed. This battery is divided into five groups; one of 7 elements for exciting the dynamo, and four of 11 elements connected in tension, or in quantity, according to the speeds required.

This arrangement enables the speed of the motor to be altered by varying the electromotive force by connecting up the four boxes of accumulators in either of the following ways:—

1st. Four boxes in series, containing 11 elements per series = 88 volts.

2nd. Pairs of boxes connected in quantity forming two groups connected in series = 44 volts.

3rd. The four boxes connected in quantity = 22 volts.

If e represents the counter-electromotive force (see Chap. III.), n the number of coils on the induction coil, N the force generated by the exciting, and N the number of revolutions per second, we have:—

$$e = N.n.N10^8.$$

And as n and N are constant in the motor under consideration, it follows that the number of revolutions will be proportional to e and also to the electromotive force E in the coil, as

$$E = e + i^2r + \text{losses}.$$

If E is varied by connecting up the accumulators in different ways, we shall obtain different speeds varying with the electromotive force, and the efficiency will remain practically unaltered. We may point out that, whatever the speed, the couple will remain constant for a certain intensity of current, as it is proportional to the product of the latter into the flux of force due to the exciting, so that for going up banks we shall not have a more powerful couple at our service than on the

level, which is a great drawback. It would be better to let the motor revolve at a high speed and have reducing gear, so as to utilise all available power and yet travel at a slow pace.

Mr. Bogard, aware of this objection, intends to alter the design of the power transmission on his car and provide it with reducing gear, so that by acting on the latter he may be able to vary the speed without altering the electromotive force as before.

The method of varying the speed of the car by varying the electromotive force simplifies the transmission to a great extent, but cannot be recommended unless the car has only to travel over fairly level ground, when decrease in speed always corresponds to decrease in the power required.

The total weight of the car in working order is about 4,840 lbs., including accumulators and motor. As we have said, the latter is excited separately. It is built by Mr. Rechniewski, who has grooved the coil, according to his usual practice, in order to protect the wires and decrease the magnetic resistance.

A current of 14 ampères at 13 or 15 volts is sent into the electros. The coil at 90 volts can absorb as much as 60 ampères and supply 6½ horse-power on the shaft. The motor weighs 480 lbs., and has a speed of 1,250 revolutions at 88 volts, of 600 revolutions at 44 volts, and of 300 revolutions at 22 volts, and when fully charged gives 45 ampères and an average of 5 or 6 horse-power.

The motor is reversed by reversing the current. It is fixed to the car-frame and works an intermediate shaft by means of a pinion and differential gearing. The intermediate shaft has pinions at its extremities, and by means of pitch chains works pitch wheels on the hubs of the rear wheels, which drive the car.

Mr. Bogard's car leaves nothing to be desired from a coachbuilding point of view, and we feel sure that when he

has modified his transmission so as to allow the electric motor to go at constant speed his car will compare with any other electric auto-car, even of American make. But Mr. Bogard will never avoid, any more than other builders, the weight of the accumulators, which limit the possibilities of electric traction. We will, however, not go back upon this point, which has already been dealt with in Chapter III.

CHAPTER IX

REPORT ON THE AUTO-CARS WHICH ENTERED FOR THE RACE ORGANISED BY THE 'TIMES HERALD' OF CHICAGO

MESSRS. J. LUNDIE AND L. L. SUMMERS, engineers, who carried out the tests on the cars entered for this competition, have handed in their report, which has been published in the 'Times Herald' of Chicago.

We are glad to be able to put this report before our readers, for this document is undoubtedly the most important ever drawn up on the subject, as it contains data valuable not only for engineers and manufacturers, but also for all those interested in self-propelled traffic.

The committee first endeavoured to choose a series of experiments which would enable comparison to be made between mechanical and animal traction. The main point was to prove that auto-cars could do the same work as other ordinary vehicles. Consequently the horse was chosen as the unit for this comparison ; and in order to facilitate this it was thought advisable to give a short account of the first experiments which were made with the object of determining the power exerted by a horse.

The Horse-Power Unit.

When the steam engine first came into use it was found necessary to compare the rate of work it could do with the rate of work done by a horse, in order that the buyer might specify the power he required by means of some known unit.

James Watt was the first to ascertain with some accuracy the average power of a horse. He found that a weight of 150 lbs. could be raised by a horse at the rate of 220 feet per minute, which corresponds, consequently, to 33,000 foot-pounds per minute as the power which a horse could exert. According to Watt, the horse could exert this power during 8 hours a day.

Later experiments have shown that this estimate was exaggerated, and that *an average horse* scarcely exerted more than 22,000 foct-pounds per minute during 8 hours, though this amount would evidently be greater if the horse worked during a shorter period.

The following table, taken from Trautwine, and based upon the above, gives some figures on this subject :—

Speed of horse in miles per hour	Traction in lbs.	Speed of horse in miles per hour	Traction in lbs.
0·75	333·3	2·25	111·1
1·00	250	2·50	100
1·25	200	2·75	90·9
1·50	166·6	3·00	83·3
1·75	142·8	3·50	71·4
2·00	125	4·00	62·5

It is evident that not only can a horse exert a considerable tractive effort for starting purposes, but he can also vary his power considerably on the road, so that he is very suitable for general traction. The maximum power of a horse has not yet been absolutely determined, but it certainly varies considerably with his weight, with the length of his stride, and with the nature of the ground he travels over. We do not believe that a horse can ever exert a greater pull than 400 lbs.

To compare an auto-car with a carriage drawn by a horse, then, it is necessary to calculate the power exerted by the motor on the rim of the driving wheels, and also the circumferential velocity of the latter. The mechanical horse-power of the auto-car in question will be found by dividing the product of these two factors by 33,000 foot-pounds,

The cost per hour for every horse-power exerted on the rim of the driving wheels can then be deduced by measuring the consumption of the motor during each test.

Where it has been possible to do so, the amount of power lost between the motor and the rim of the driving wheels and the effect of the different methods of regulation upon the fuel consumption have been determined.

Fuel Consumption Tests.

These tests bore upon the consumption of the motor for the various loads imposed by practice.

In order that all the motors should be tried under the same conditions, gasoline, having a density of 0·658, at an estimated cost of 1*d.* per lb.,[1] was supplied to them from the same tank.

The cost of a kilowatt-hour was calculated on the basis of an average accumulator efficiency of 75 per cent.

Maximum Pull Exerted by Auto-Cars.

It was considered advisable to determine this in order to be better able to compare the auto-car with the horse. The cars tried were all built to exert a comparatively light pull at great speed, and not a heavy pull at low speed.

The maximum pull exerted was found by opposing a resistance to the wheels till the motor stopped.

The Duryea car, for instance, only exerted a pull of 187 lbs., whereas we have seen that one horse could pull 400 lbs.

During none of the tests, however, could the driving wheels be made to skid on the ground, so it is possible that the tractive force could have been very much increased without skidding by using reducing gearing.

When belting was employed on the test cars for transmitting the power, it was found that the latter reached its

[1] This is the estimate taken in the tables pp. 202–204.

maximum value just before the belts slipped on the pulleys. Mr. Macy's car could not be tested thoroughly on account of the defective condition of the belting employed. The Lewis auto-cycle broke its driving chain when the maximum pull was being measured. As to the electric motors, the maximum pull obtainable was limited only by the heating effects of the strong current employed.

A great difference in the consumption of the several cars on trial is shown in the tables (pp. 202 to 204). This is due solely to the nature of motor employed. Nearly all the single-cycle motors burn a great deal of fuel, caused generally by the improper combustion of the gases. This is the case with the Lewis and the Haynes cars. Whilst these cars were being tested the exhaust gas was so charged with unconsumed carbon that it was found necessary to have a special exhaust pipe and fume blast to convey the fumes from the testing room.

It must be acknowledged, however, that single-cycle motors work much more regularly than the others.

It is a pity that the igniting apparatus on the Duryea car should have got out of order, putting a stop to further experiments. All those interested in the construction of gas motors know that the cycle obtained is less economical than that made by steam. The average efficiency is still lower when the gas motors are used for traction, for the following reasons :

1st. Because work is sacrificed in driving the machinery.

2nd. Because a 4-horse-power motor, for example, seldom works at its normal speed and power, so that it cannot have a high efficiency.

This is why the fuel consumption of auto-cars is comparatively high.

With regard to the Benz motor, attempts were made to simplify the transmission gear by having only two ranges of speed.

Speeds between these two extremes were obtained by regulating the amount of carburetted mixture supplied, but a glance at the tables (pp. 202 to 204) shows at once that this ease of control and simplification of mechanism is more than neutralised by the very large amount of fuel which the motor consumes when it is not working at its normal speed.

Evidently the useful horse-power exerted on the rim of the driving wheels when the motor is working under the best conditions of speed and power costs about one-fourth of its cost when working under the most unfavourable conditions.

In such cars as the Duryea car, where the speed of the motor is always constant, the efficiency is in proportion to the amount of work done, so that an auto-car may often climb a bank at the same speed as on the level without consuming more fuel, for the very reason that the extra power required is compensated by a better efficiency.

The position of the motor on the car and the method of transmission employed greatly influence the amount of vibration on the car.

When the motor is mounted at right angles to the driving axle, as on the Benz car, the vibration is rather strong, especially at starting. Messrs. Haynes & Apperson's car is fitted with a motor having two cylinders arranged upon opposite sides of the driving shaft, and this arrangement gives less vibration.

Electric Cars.

The exact efficiency of an electric auto-car is somewhat difficult to determine. The storage battery efficiency varies with the discharge rate, which again depends upon the work done. The cost of electric power varies from town to town, and this fact must be taken into consideration when calculating the cost of electric traction.

The life of the accumulators also will depend upon the kind of work which the car is made to do.

Single and Double Motors.

Mr. Sturges and Messrs. Morris & Salom's two cars enabled an interesting comparison to be made. Both cars employ Lundell motors, but whilst Mr. Salom has two motors, one for each driving wheel, Mr. Sturges only employs a single 3-horse-power motor working on a differential shaft.

The motor efficiency in these two cars is practically the same, but of course the transmission gear is heavier with two separate motors than with one.

We do not think the advantage of being able to couple up the motors in series, or in parallel, quite justifies the employment of two motors, and the only real advantage of this arrangement is to enable the driving wheels to run independently of one another when turning round corners instead of having to employ differential gearing to effect this.

(Signed) JOHN BARRETT,
Chairman of the Committee.

L. L. SUMMERS
JOHN LUNDIE } Engineers of Tests.

POWER AND DUTY TESTS OF AUTO-CARS.

Electric Cars.

Car	No. of run	Pull exerted in pounds	Horse-power exerted at rim of wheel	Total horse-power developed in motor	Mechanical efficiency	Electrical input in horse-power	Kilowatts supplied by accumulators per horse-power at rim of wheel	Foot-pounds at rim of wheel per kilowatt-hour	Cost per horse-power-hour at rim of wheel (pence)	Maximum pull exerted (pounds)	Horse-power consumed in mechanism	Speed in feet per minute	Input: Volts	Input: Amp.	Heating of bearings
Morris and Salom .	1	25·5	0·78	1·12	0·70	1·36	1·74	1,138,000	8·00	—	0·34	1,025	97	10·5	
Lundell motor .	2	29	1·78	2·46	0·72	2·90	1·63	1,215,000	7·49	—	0·68	2,015	96	22·5	
Sturges Electric Motocycle Co. .	1	41	0·41	0·62	0·66	0·99	2·42	818,000	11·13	121	0·21	370	35	21	
Lundell motor .	2	42	1·14	1·53	0·74	1·94	1·70	1,165,000	7·82		0·39	892	69	11	

POWER AND DUTY TESTS OF AUTO-CARS.

Car	Number of run	Pull exerted in pounds	Horse-power exerted at rim of wheel	Total horse-power developed in cylinder	Mechanical efficiency	Gasoline, pounds consumed per hour	Gasoline, pounds consumed per horse-power-hour at rim of wheel	Foot-pounds at rim of wheel per pound of gasoline	Cost per horse-power-hour at rim of wheel (pence)	Maximum pull exerted (pounds)	Horse-power consumed in mechanism	Speed in feet per minute	Remarks
De la Vergne .	1	37	0·70	1·41	0·50	3·24	4·63	428,000	4·63	162	0·71	619	
	2	51·8	1·57	2·97	0·53	4·45	2·83	700,000	2·83		1·40	1,000	
Duryea (Springfield) .	1	83·8	1·10	1·69	0·65	4·01	3·64	545,000	3·64	187	0·59	432	Trouble with igniter
	2	88·5	1·16	1·75	0·65	3·78	3·24	623,000	3·24		0·59	434	
Haynes and Apperson .	1	23·1	0·26	0·87	0·30	5·78	21·8	91,000	21·8	119	0·61	376	Two cylinders in use—one supplying power
	2	39·3	0·95	2·23	0·43	5·75	6·04	327,000	6·04		1·28	796	
Lewis (Chicago) . .	1	49·9	0·53	1·06	0·50	3·29	6·20	319,000	6·20	109	0·53	353	Chain broke
	2	17	0·25	0·90	0·28	3·28	12·8	155,000	12·8		0·65	491	
Macy (New York) . .	1	52·1	0·83	2·31	0·36	3·22	3·90	515,000	3·90	103·7	1·48	521	Belt slipped
	2	87·2	2·50	5·18	0·48	4·90	1·96	1,010,000	1·96		2·68	945	
Mueller and Sons (Mueller-Benz Motor) .	1	92·1	1·18	1·79	0·66	3·50	2·96	669,000	2·96	135·4	0·61	423	
	2	42·3	0·69	1·46	0·47	3·87	5·6	354,000	5·6		0·77	540	
	3	38·6	0·66	1·47	0·45	3·77	5·71	347,000	5·71		0·81	564	
	4	73·4	2·18	3·75	0·58	3·40	1·57	1,268,000	1·57		1·57	984	
	5	34·7	1·23	3·09	0·40	4·15	3·37	588,000	3·37		1·86	1,168	

DETAILS AND DIMENSIONS OF MOTORS.

Car	Weight on driving wheels	Weight on steering wheels	Total weight	Wheel base	Distance apart of driving wheels	Distance apart of steering wheels	Radius of driving wheels	Radius of steering wheels	Position of driving wheels	Nature of tyre employed	Fuel used	Number of cylinders	Bore of cylinders	Stroke of piston	Nature of bearing
	lbs.	lbs.	lbs.	ins.	ins.	ins.	ins.	ins.					ins.	ins.	
De la Vergne (New York)	1250	430	1680	66·7	—	—	23·7	18·2	rear	solid rubber	gasoline	1	5·12	6·62	roller
Duryea (Springfield)	729	479	1208	57·5	55	53·7	22·8	18·7	,,	pneumatic	,,	2	4	4·5	—
Haynes and Apperson	829	421	1250	54	55·2	55·5	17·8	17·9	,,	pneumatic	,,	2	4	4	ball
Lewis (Chicago)	900	780	1680	56	46·6	46·5	22·9	16·7	,,	solid rubber	,,	1	5	5	roller
Macy (New York)	1440	385	1825	67	52	52	23·8	17·9	,,	solid rubber	,,	1	5	7	roller
Morris and Salom	1260	390	1650	49	44·2	36·1	19·8	14·2	front	pneumatic	accumulators	2 motors	—	—	ball
Mueller	1251	385	1636	73	50·2	47·8	24	18·4	rear	solid rubber	gasoline	1	5·5	6·25	roller
Sturges	2085	1450	3535	65	57	57	25·1	23·2	,,	solid rubber	accumulators	1 motor	—	—	plain

CHAPTER X

LUBRICATION—TYRES—BEARINGS—SPRINGS—AXLES—CARBURATORS—IGNITION—STARTING—VIBRATION

STEAM CARS.

THE lubrication of valves and cylinders is one of the essential conditions of good working either in auto-cars or in steam tramways. The old system of oil cups has been done away with long ago for stationary engines, and we now use automatic lubricators instead. These can be divided into two main classes : those worked physically, and those worked mechanically. We will examine these two types and their application to auto-cars.

This is the problem we have to solve : to find a lubricator which can be regulated at will, which will work continuously despite the vibration of the engine and change in temperature, which will lubricate with every stroke of the piston, and which will start and cease working automatically when the car starts and when it stops.

The first class of lubricators can again be divided into sight-feed and non-sight-feed lubricators, which latter, however, need not be considered.

Sight-feed lubricators are either with descending or with ascending oil drops. The former are simpler in construction, being generally provided with valves which close under steam pressure and open at exhaust to allow the oil to pass through. This kind of lubricator, which is not over reliable for stationary engines, gets out of order at once on auto-cars on account of the speed and vibration of the car.

There are other sight-feed lubricators with descending drops, similar to those employed for plummer blocks, with this difference, however, that the former have a small tube which leads the steam to the upper part of the cup so as to balance the pressure from the cylinder and enable the drops to pass through the tube.

One sees at once that the variation of steam pressure added to the jolting of the car have a disturbing effect inside the oil cup, and that the steam condensed in the cup mixes with the lubricant, and sometimes even takes its place.

The Consolin type of lubricator with descending drops employs condensed steam.

An oil reservoir is connected to the boiler by a coiled tube in which the steam condenses slowly. The water thus formed accumulates at the lower part of the tube and forces the oil up, which passes through a variable opening in the lower part of a glass tube filled with water. Owing to its lighter weight compared with water the oil rises in this tube and then passes into a copper tube connected to the cylinder. This system has drawbacks, as the oil is not supplied regularly, and the glass tubes are liable to burst and force out the oil and steam.

The chief drawback of physically worked lubricators for auto-cars is that the lubricator continues working when the car has stopped, and if the cock is not closed the oil empties itself into the cylinder, and the lubricator must be readjusted before starting again.

We think we have sufficiently proved that this class of lubricator is not suitable for auto-cars, so that we must resort to mechanical lubricators.

Mechanical lubricators can be divided into two classes:

Those with direct action, and those with reducing gear.

The first class includes all lubricators with small pump worked by the engine. These might be suitable for a powerful engine with slow speed, but not for an engine with high speed requiring little oil.

Amongst lubricators with reducing gear we find suction apparatus and compression apparatus. The latter are vastly superior. They invariably work well, as some lubricant is supplied with each stroke of the piston.

Although the 'Mollerup' lubricator gives exceedingly good results, it is open to the following objections: the ratchet-wheel and the pawl are noisy, and wear out rapidly. The supply of oil by the lubricator is regulated by a numerical progression, as the wheel cannot travel less than one tooth at a time, so that, if 3½ ozs. of oil supplied during any given time is insufficient, the next possible quantity is 7 ozs., which may be more than is required. Again, if the apparatus which, for instance, exhausts its supply in 6 hours with two teeth, is required to work 7 hours without refilling, the only method of regulation is to use one tooth instead of two, so that the lubricator works for 12 hours, which is more than required, and may not supply sufficient lubricant during the time it is at work.

Another objection sometimes made is that this lubricator is too heavy for some private cars.

These disadvantages have been overcome in the 'Terminus' lubricator, shown in elevation and in section on Figs. 97 and 98. A piston, *D* (Fig. 98), worked by a screw, *E*, works in the pump barrel *A*. The screw *E* is actuated by a wheel *G*, driven by an endless screw, connected to a wheel *I* and nipping lever which takes the place of the ordinary ratchet-wheel and click, and is worked by the engine itself.

To fill the Terminus lubricator, oil is poured into the cup, and is drawn in by raising the plunger by means of the wheel.

The oil is forced by the descending plunger through a small copper tube with a retaining valve to the part to be lubricated. This valve can only be raised by the pressure of the oil, so that the tube cannot empty itself whilst the car is not moving.

The Serpollet, Scott, and other auto-tramcars employ the Terminus lubricator, a pattern made to hold $10\frac{1}{2}$ ounces of lubricant being found suitable for their purpose. This lubricator will work the whole day and travel 80 miles without refilling, which represents a consumption of 0·13 oz. per mile and a delivery of 0·001128 dram per stroke of piston.

FIG. 97.—The Terminus Lubricator.

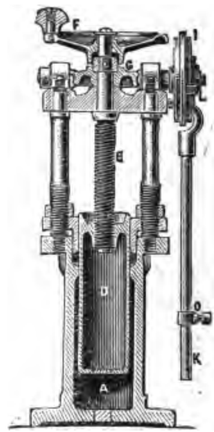


FIG. 98.—Section of the Terminus Lubricator.

A lighter pattern of this lubricator is made, and is very suitable for private auto-cars. It is made of aluminium, in two sizes, to hold $1\frac{3}{4}$ and $3\frac{1}{2}$ ozs. of oil respectively.

PETROLEUM MOTORS.

The cylinder is the most important part which requires lubrication in petroleum motors.

We no longer work against a constant pressure, as in steam cylinders, but the rise in temperature at the time of explosion and the complete exhaust and consequent carrying away of an appreciable quantity of the lubricant render this sort of lubrication exceedingly difficult.

We will pass over lubricators worked on physical principles for the same reasons we have given in our description of cylinder lubrication, and we will give the preference to lubricators worked on mechanical principles. Here the question of weight, volume, and simplicity of parts and working is even more important in petroleum than in steam cars.

The Drevdal 'Oleopump,' shown on Figs. 99 and 100, combines all the requirements for petroleum cars. It consists

FIG. 99.—Elevation of the Drevdal Oleopump.

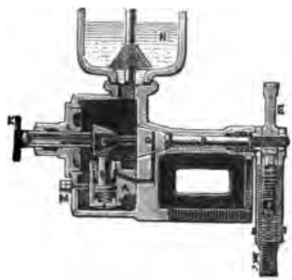


FIG. 100.—Section of the Drevdal Oleopump.

of a pump barrel *A* containing a piston *B* worked by a double cam *C* fixed to the spindle *D*. A pawl *F*, carried on the arm *I*, drives the ratchet-wheel *E*, which works the spindle *D*.

The arm *I* is connected to the motor by a small rod, and has a limited stroke. The oil is supplied by means of the cone *G*, which has openings in it so arranged that the oil reservoirs *H* and the delivery pipe leading to the part to be lubricated communicate alternately with the barrel of the pump *A*.

When the piston *B* is set free by the cam *C* it is raised by a spring, and causes the oil to be drawn into the pump barrel.

As the shaft *D* revolves it brings the cam against the piston *B*, which forces the oil to the delivery orifice.

Suction therefore occurs instantaneously twice per revolution, and delivery is practically continuous.

This suction can never fail, for the following reasons :

1st. The oil is always sucked in under pressure, as it is taken from the chamber which communicates with the oil reservoir *H* placed above it.

2nd. There are no valves.

3rd. The orifices are in direct communication at the time of suction.

The lubricant used with petroleum cylinders is fluid, and facilitates suction, which is not the case with steam cylinders.

The delivery cannot fail any more than the fall of the plunger upon which it depends.

In order to regulate the Oleopump the arm *I* is connected to the motor so as to drive one tooth of the ratchet-wheel at a time ; the delivery of oil is then regulated according to the requirements of the motor by turning the wheel *K*, and setting its pointer to any of the following positions : *large*, *mean*, *small delivery*, which are marked upon the apparatus.

The glass reservoir *H*, which is filled with the oil, has graduated divisions from 50 to 100 grammes,[1] so that the quantity of oil consumed can be gauged.

The vibration of the car does not interfere with the working of this oil pump, as suction takes place in the chamber inclosing the working parts, which is always full of oil.

For motors requiring lubrication at several points, the Oleopump can be made with two or three delivery pipes, each leading to the part to be lubricated.

It is also made with an endless screw and pulley with belt for rotary or high-speed engines. A nipping lever, as used in the Terminus lubricator, can also be substituted for the ratchet and pawl arrangement.

[1] 1·75 to 3·5 ozs.

Messrs. Drevdal have also brought out an aluminium Oleopump which is much lighter, only weighing 10 lbs.

The Oleopump has, amongst others, the following advantages :

1st. The parts are strong, and work slowly, immersed in oil, so that there is hardly any wear, and no other lubrication is required.

2nd. The pump is easily taken to pieces for repairs.

Messrs. R. Henry, of Paris, have brought out an 'Oleopolymeter' for the lubrication of petroleum cars, and this apparatus gives excellent results. We regret not being able to give a detailed description of it, as everything pertaining to lubrication is of the utmost importance to those interested in the question of self-propelled traffic.

TYRES.

One of the questions of the day is certainly that of tyres for auto and other cars.

Iron tyres are more generally employed, although they are inferior to rubber, and especially to pneumatic, tyres from every point of view. In fact, there is hardly any need to point out the advantages of the latter in reducing the pull as well as the wear and tear of the car.

Again, everything considered, rubber tyres are really cheaper in the long run than iron tyres, and if the latter are still used to such a great extent we think it is chiefly owing to the force of habit, which is always difficult to overcome.

The Michelin Co., whose speciality is the manufacture of pneumatic tyres for cars, carried out several experiments at Clermont-Ferrand in France, and proved that the pneumatic tyre unquestionably decreases the pull and wear and tear of a car to a considerable extent.

The car runs more smoothly with pneumatic tyres ; there is less jolting, and the wear and tear is reduced ; we will, how-

ever, not go into that question, but will deal rather with the decrease in the pull required to haul the car.

Comparative tests were made with iron and pneumatic tyres on different kinds of road, at different speeds, and with different loads.

EXPERIMENTS CARRIED OUT IN THE SNOW.

	Iron wheels	Pneumatic wheels
Car, walking pace, empty	39·29	25·19
" " with load of 330 lbs.	39·12	27·96
" trotting pace, empty . . .	65·12	33·59
" " with load of 330 lbs.	68·57	39·51

EXPERIMENTS CARRIED OUT ON A MUDDY ROAD.

	Iron wheels	Pneumatic wheels
Car, walking pace, empty . . .	35·2	23·10
" " with load of 330 lbs.	38·06	27·34
" trotting pace, empty . . .	43·01	28·53
" " with load of 330 lbs.	50·73	31·15

AVERAGE RESULT OF EXPERIMENTS CARRIED OUT ON DRY, NEW, DUSTY MACADAM, GOOD ROAD, WITH GRADIENTS FROM 1·2 PER CENT. TO 5·8 PER CENT.

	Iron wheels	Pneumatic wheels
Car, walking pace	38·32	30·91
" trotting pace	44·90	35·09
" walking pace, load of 660 lbs. .	45·65	42·10
" trotting pace, " " . .	65·34	36·08

The above figures clearly demonstrate that the pneumatic tyre requires less pull to haul the car than the iron tyre, and that the advantage it has over the latter is greater at a trotting than at a walking pace, and is also greater when the car is loaded than when it is empty.

Another set of experiments with pneumatic tyres filled at different pressures gives the following results:—

	Wheels with iron tyres	Pneumatic tyres with 43 lbs. pressure	Pneumatic tyres with 64 lbs. pressure
Car, empty, trotting pace .	46·64	34	39·49
„ 660 lbs. walking pace	47·96	44·75	43·91
„ 660 lbs. trotting pace	64·20	45·14	51·96

The average of all these experiments on different kinds of roads, and at different speeds, comes out as follows :—

Pneumatic tyres	Iron tyres
100 lbs.	132·7 lbs.

Without going farther into the matter, we may say without exaggeration that pneumatic tyres have such an advantage over the others that their application to coachbuilding is merely a question of time.

There is no doubt that they will do even better service for auto-cars for self-propelled traffic, which, although quite a new industry, promises to become an enormous one.

Not only must we spare the motor as far as possible, whether it be an animal or a mechanical one, by decreasing the pull, but we must also consider the question of noise and vibration.

With a pneumatic tyre we suppress the deafening noise complained of in the first auto cars built with iron tyres. The motor works more steadily, the bolts do not work loose, and the stops are consequently less frequent. Pneumatic tyres can either be fitted to wooden wheels with wooden rims or with sockets, or else to metal hub and spokes.

Wooden Wheels.—The rim of the pneumatic tyre is fitted to the wooden rim in which the spokes fit, or else the latter fit into metal sockets riveted to the rim of the pneumatic tyre itself. The socket arrangement has a better appearance, because the tyre is less wide by the thickness of the wooden rim ; it is quite as strong as the first arrangement, and seems already to be adopted by important firms of coachbuilders.

Metal Wheels.—The spokes are either straight or tangential, the latter being preferred for the driving wheels.

Spokes, whether straight or tangential, are always in tension, the hub of the wheel being suspended, so that the spokes of the half of the wheel that happens to be uppermost are always

FIG. 101.

in tension, whilst there is no strain whatever on the spokes of the lower half.

With wooden wheels the spokes work in compression, so that on running over a large stone, for instance, the jar is transmitted to the hub, whilst with iron spokes it is distributed over part of the circumference of the wheel, so that the jolt is much reduced when it finally reaches the hub.

It follows from this that of two wheels, one with wooden and the other with iron spokes, equally loaded, of equal diameter, with the same tyres, and working under the same

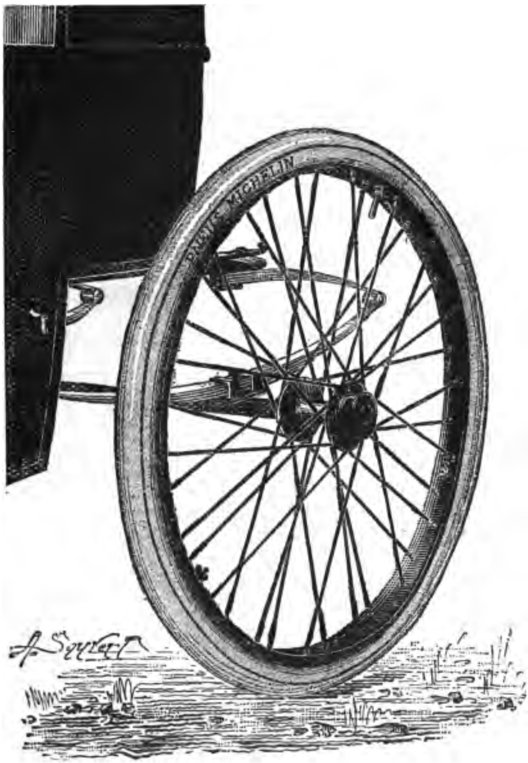


FIG. 102.

conditions, the wooden wheel will jump much more than the other, and will consequently wear more rapidly.

The Michelin pneumatic tyre and its method of attachment to wooden wheels and to steel spokes is shown in detail on Figs. 101, 102, and 103.

Many people hesitate to employ pneumatic tyres for fear of punctures, but we think they are wrong, because those who have used them find that the outer covering of the tyre is

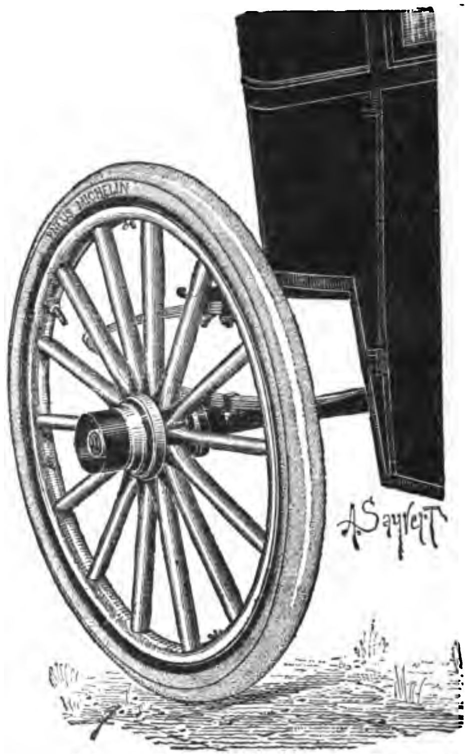


FIG. 103.

sufficiently thick to protect it from nails, flint stones, and broken glass which may be found along the road.

Indiarubber tyres are also of immense service. Mr. Vinet, who was the first to start rubber-tyred cabs in Paris, in 1895, has devised an arrangement by which it is impossible

for the tyres to slip off the wheel, which is a very important point.

The firms of Edline and Torrilhon have also gone into the manufacture of indiarubber tyres.

SPRINGS—AXLES—BEARINGS.

Springs and axles are important parts of an auto-car on account of the dangerous consequences their failure entails. Car builders should only get these parts from the best makers, as the material employed in their manufacture cannot be too good.

The type of springs generally adopted is known as the 'C' spring, and is well adapted to attachment to T- or U-shaped underframes.

The rear springs are often fixed to a movable iron cross-bearer, which can be adjusted by a regulating screw so as to give the required tension to the pitch chains.

'Straight' springs are generally preferred for heavy loads. They are placed at the rear of the car, and are better adapted for brakes which act on the tyres than the former kind of spring.

'C' springs are often used for light cars. They are elegant, work gently, and absorb a good deal of the motor vibration.

The greatest care must be given to the question of elasticity and deflection of the spring, whatever type be adopted.

In the bending test a tempered steel spring must show an elongation of 0·5 per cent. without permanent set.

Messrs. Hannoyer, of Paris, who have made a speciality of springs and axles, employ an exceedingly interesting machine for testing the elongation and flexibility of springs.

Two kinds of axles may be employed for auto-cars :—

1st. The ordinary axle, which is sufficiently well known, and needs no description.

2nd. The axle with ball or roller bearings.

Bicycles have proved the value of ball bearings. It is

evident that the rolling friction is much less than the sliding friction which takes place with ordinary axles.

With heavy auto-cars it is necessary to have several rows of balls to avoid crushing.

Messrs. Hannoyer fit their axles with balls inclosed in a removable box. There are four, six, or eight rows of balls, according to the length of the journal, which is proportional to the load carried.

Front axles, as we know, are generally attached to upright pivots, and here again it is most important to have good material and good workmanship. The iron used should be thoroughly tested, and should have an elongation of 28 to 78 per cent. tension, with a breaking strain of at least 22 tons per square inch.

Roller Bearings.—One of the objections, however, to ball bearings is that the balls only touch the races or ball paths at one point, so that all the weight is carried by one or several balls—according to the number of rows employed—at any moment of time, and when heavy loads are carried the balls either crush or indent the races. This objection, of course, does not hold with light weights such as are carried by cycles or auto-cycles, but for auto-cars for several passengers it is another matter, and we think that possibly roller bearings, which do not meet with the above objections, might be found very suitable.

Information regarding these bearings has been kindly supplied to us by the secretary of the Roller Bearings Company of Westminster, and it may interest those concerned in the manufacture of auto-cars.

The bearing consists of two sets of rollers, the inner ones forming the bearing and the outer ones are spacers which keep the main rollers from touching each other. The latter drive the spacers, but are themselves driven by the axle. The spacers, or subsidiary rollers, do not touch the casing, but are prevented from moving inwards by the 'path' and outwards

by a 'live ring' which embraces them, and which they drive at their own speed; lateral motion is also prevented by the knobs on the subsidiary rollers, which are so constructed that they engage the rollers and the path at their normal diameters, so that there is nothing in the nature of a flange which involves scrubbing, but the whole series of rollers truly rolls.

It is claimed, therefore, that a roller bearing is one in which there is no scrubbing of parts, and consequently does not require lubrication; that the rollers will bear the stresses that ordinary boxes have to meet; that the saving in starting effort and in pull is very considerable.

To demonstrate the latter, experiments were carried out at Lancaster with trucks weighing $2\frac{3}{4}$ tons on gradients of 1 in 44. Comparative tests were made between a truck fitted with ordinary oil boxes and one fitted with roller bearings, and it was found that the tractive effort was as 6·32 to 1 in favour of the latter, and that on the level the starting effort required was 6·53 lbs. per ton for the truck with roller bearings as against 41·68 lbs. per ton for the truck with oil boxes.

We understand that these bearings have been running successfully for some time on a train of six carriages belonging to one of the principal English railways, and also on several suburban tramways. In view of these successful results it will be interesting to see the application of roller bearings to auto-cars, and ascertain experimentally whether the same advantages will accrue to this new application as have apparently already been effected on railway and tramway traction.

Joints.—Vulcanised fibre is used by almost all auto-car builders. It is used for joints in petroleum motors and for small gearing for power transmission. This material has rendered good service in electricity, and will do so still more for auto-car, car, and tramway purposes.

CARBURATORS—IGNITION—STARTING—VIBRATION.

Carburators.—Sufficient importance is not given to carburators in descriptions of petroleum motors; yet this is one of the main and most sensitive parts upon which the good working of the car depends to a great extent. In our opinion, manufacturers have not given enough attention to the matter, and carburators are still open to much improvement.

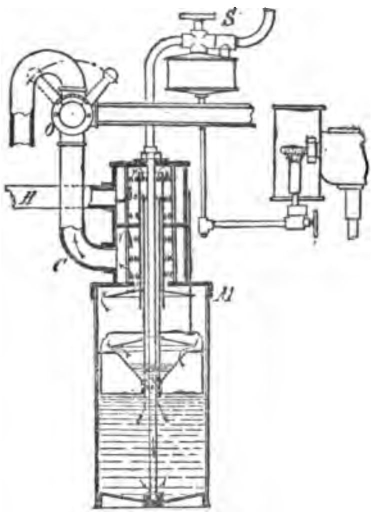


Fig. 104.—Daimler Carburator.

They are all designed on the principle of vaporisation of petroleum spirit by means of an air current. Consequently the lighter portions of the oil are first vaporised, so that its density increases as the reservoir is emptied till it reaches a point when carburation can no longer take place under good conditions, and the motor stops working. The reservoir must then be completely emptied, and refilled with fresh gasoline.

The carburators employed by Mr. G. Daimler are open to this objection.

Figs. 104 and 105 show two types of carburator patented by Mr. G. Daimler. The older pattern, on Fig. 104, consists of a cylindrical reservoir, a float, a level gauge, a feed-tube for the gasoline, apertures for the air to pass in and out before and after carburation, a regulating cock, and a cylindrical cap with holes.

These are all shown on the drawing. Petroleum is fed

into the reservoir *P*, and the supply controlled by means of the cock *S*. The float slides in a tube open at its upper end and immersed in petroleum at its lower end. The air coming from *H* bubbles through the petroleum and emerges at *C* after passing through the cap *M*. A three-way cock *O* controls the mixing of air and carburetted air drawn into the motor, and is so designed that the supply of air varies inversely with the supply of carburetted air. Before passing into the carburetting apparatus the air is reheated by a burner not shown on the cut. This reheating is not required in summer, but in winter it greatly assists the process of carburation.

This apparatus has the following disadvantages: 1. The gasoline is not properly used up, as the denser portion is not evaporated. 2. The liquid does not keep a constant level in the reservoir *P*, which should, on the contrary, be fed automatically.

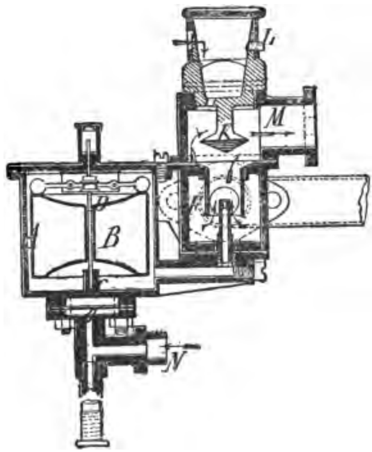


FIG. 105.—Daimler Carburator.

The apparatus shown on Fig. 105 has been designed to overcome this drawback. Petroleum coming from *N* passes through the groove *O*, the valve *C*, and fills the reservoir *A*. When the gasoline has reached the level of the top of the tube *I* in the reservoir the float *B* closes the valve *C* and stops the supply. The reservoir *A* communicates with the pipe *I*, so that the air from the chamber *F* passes up this tube, vaporises the gasoline surrounding the top of the tube, and then goes into the cylinder of the motor. The proportion of air in the explosive mixture can be varied at will by means

of the special key L, which allows more or less air to enter. The petroleum is maintained at a constant level by the float B, so that no overflow can take place at I.

This carburator works well, and its construction is very simple, but, as in the carburator previously described, the lighter portion of the gasoline is first vaporised, and the denser portion may in time cause the motor to stop. Again, the carburation of the air depends upon the surrounding temperature, so that to obtain a constant proportion in the mixture the key L must be regulated according to whether the motor works in the sun or in the shade, in the morning or in the evening, in summer or in winter. This regulation is very delicate to effect, and it is often very difficult to obtain the proper quantity of air required for good working. The Loyal carburator described in Chapter IX. overcomes some of these disadvantages. Petroleum is supplied into the lower part of the reservoir, so that the heavier portion of the liquid is first carburetted, and all the petroleum can be used. The quantity of liquid drawn in for each stroke of the piston depends upon its level in the reservoir C' (see Fig. 80), for the following reasons: 1. Because the valve will be raised off its seat more easily as the pressure increases, so that it will become a function of the height of the liquid in C'. 2. Because the amount of petroleum which passes through the valve will also be proportional to this height.

We think there ought to be no difficulty in designing a carburator which would supply a constant mixture independently of the surrounding temperature. An arrangement similar to that shown on Fig. 106 might possibly meet the case.

In short, what do we require so that a constant amount of petroleum vapour shall be supplied to the cylinder, through an orifice of constant section, for every stroke of the piston?

Two conditions must be complied with:

1. The pressure controlling the admission of carburetted vapour must be constant.

2. The density of the vapour must be constant.

Let us examine Fig. 106. Petroleum, under a pressure P, due to the height of the reservoir, passes from A into the receiver R, which is heated by a burner B.

As it falls into the heated receiver it vaporises and gives rise to a pressure which increases till it is equal to the pressure P; the pressure in the reservoir is therefore constant.

The vapour density for a given pressure will therefore depend upon the temperature, and consequently will not vary if the latter be constant. The temperature is shown by a thermometer T immersed in the carburetted vapour, and the

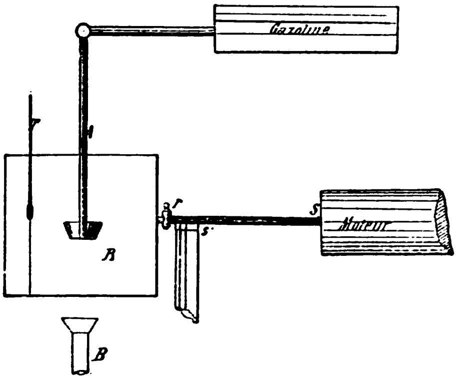


FIG. 106.

burner could easily be controlled to give the required temperature, in accordance with which the cock r has been regulated. The air supply pipe must have a retaining valve s' to prevent the petroleum vapour from passing into the atmosphere.

At first sight one would think that the vapour would condense immediately on leaving the heated reservoir R, but this is not the case, because when it emerges from the cock r it expands and mixes with a large volume of air before passing into the cylinder. It might, however, be advisable to place the air pipe near the burner B, so as to heat it.

We must not count upon the heat of the exhaust gas for heating the reservoir *R*, because this sort of heat is not constant, and does not exist when the engine is started. The above arrangement appears to us simple, effective, and exempt from the drawbacks of the other apparatus which have hitherto been designed.

Ignition.—This used generally to be done by means of a flame. There are three ways of proceeding.

1. By suction of the flame used in non-compression motors.
2. By transport of flame.
3. By propagation of flame.

These last two methods are applicable to single or Otto-cycle motors with preliminary compression, but they need not be described, as they are not at all applicable for road locomotion purposes, because their parts are so sensitive, and because the flame is easily extinguished by draughts.

This method of ignition by flame has therefore been practically abandoned, even for stationary engines; and the incandescent tube, already described, has been used instead with success.

Ignition is arranged to take place automatically at the end of compression for small motors not exceeding 4 or 5 horse-power.

The tube is so placed in the explosion chamber that when the gases have been exhausted a certain amount of burnt gas still remains at the end of the cylinder and in the tube. When fresh gas has been admitted and compressed it only mixes slightly with the burnt gas in the incandescent tube, and only when compression is at its maximum can the explosive mixture, after forcing the inert gas to the end of the tube, cause the explosion by coming into contact with the heated sides of the tube. We have already mentioned that leakage or an unequal supply of gas may alter the amount of compression, and consequently the ignition point; because if

compression is insufficient ignition will fail, and if too great explosion will take place before the end of the return stroke, so that the motor will tend to revolve in an opposite direction. However, in well-built motors this method of ignition is found very satisfactory. Any kind of burner may be used for heating the tube so long as it keeps the latter at a uniform temperature as far as possible. Longuemarre burners are much employed, and give good results.

For large motors we prefer a separate igniter, worked mechanically by the motor, which connects an incandescent platinum wire with the gas at the moment explosion is required.

In some cases, where a tube is used, the burner can be dispensed with, the compression and explosion of the gas being sufficient to keep the tube at the required temperature. The motor is started by heating the tube with a small portable lamp, which is the method adopted in the Loyal motor, described in Chapter IX.

Ignition by an electric spark is another method much employed.

As one knows, the temperature of an electric spark is very high, and therefore causes instantaneous explosion, which is a great advantage. Three conditions are essential to good working :—

1. The spark must occur at the exact moment it is required.

2. It must be applied to that part of the gas richest in hydrocarbons.

3. It must have a high temperature.

Theoretically, these conditions are easily complied with but not so practically.

The spark must be hot; consequently, unless a very large coil is used, a low E.M.F. must be employed.

The points producing the spark must be close together; any dirt deposit, therefore, may cause the spark to fail. To

avoid this the igniting plug must be placed as close as possible to the gas admission port, so that on entering the gas may clean the end of the plug.

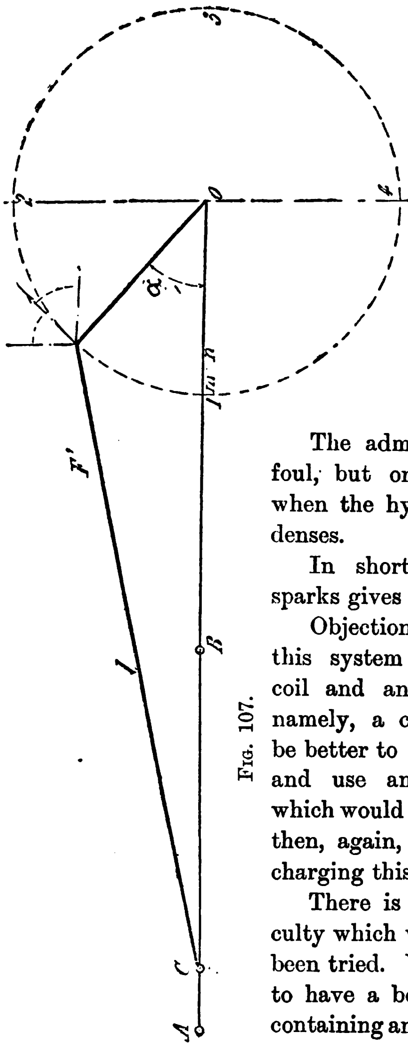


Fig. 107.

The portion of the gas in that part of the cylinder is also richest in hydrocarbons, so that the average temperature is sufficient to prevent tar or grease deposits on the plug.

The admission valve never gets foul, but only the exhaust valve, when the hydrocarbon vapour condenses.

In short, ignition by electric sparks gives excellent results.

Objection is often raised that this system requires an induction coil and an awkward generator—namely, a cell. It would perhaps be better to dispense with this cell, and use an accumulator instead, which would take up less room ; but then, again, there is the bother of charging this accumulator.

There is a way out of the difficulty which we do not think has yet been tried. Would it not be possible to have a box, working on a slide, containing an accumulator, a coil, and

a small dynamo whose driving shaft is fitted with a small pulley outside the box?

When the car is running the box could be pushed along the slide by means of a lever till the pulley of the dynamo was brought against a disc on the motor driving shaft, which would cause it to revolve. All the parts could be held in a box 12 inches by 8 inches, and no attention need be paid to charging the accumulator.

The motor could also be started by means of this apparatus by allowing the pulley to turn the motor when out of gear by sending the current from the accumulators into the dynamo, and if the accumulators were sufficiently powerful they could be used for lighting the car as well as for starting the motor.

Vibration.—Car vibration is entirely caused by the pulsations of the motor whilst working.

Suppose for one moment the motor to be going at its normal speed without explosion being required to keep up that speed, then jerks will be felt if the motor has only one cylinder, or, in other words, if it is not balanced.

Let (Fig. 107) $P + Q$ equal the weights of the piston and connecting rod and N the number of revolutions per minute. We shall have

$$x = Ac = mn = r\,(1 - \cos a),$$

whence the velocity of translation will be

$$v = \frac{dx}{dt} = r \sin a \,\frac{da}{dt},$$

and the acceleration

$$j = r \cos a \left(\frac{da}{dt}\right)^2;$$

or

$$j = r \cos a \left(\frac{N}{60}\right)^2.$$

The pressure due to the *vis viva* of the moving parts will be

$$F_x = \frac{P + Q}{g} \,.\, r \cos a \left(\frac{N}{60}\right)^2;$$

from which

$$F_x = K' \cos \alpha,$$

K' being a constant which depends upon the velocity of rotation and the weight of the moving parts. The pressure F_x will disappear when $\alpha = 90$, and will be maximum at the beginning and end of each stroke, as shown on the diagram Fig. 108.

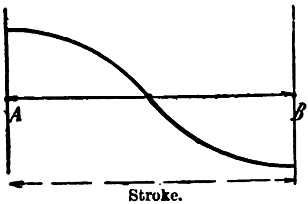


FIG. 108.

Following a similar method of calculation for the path travelled by the connecting rod along *oy*—assuming, to avoid complication, that half the weight of the rod describes a circle of radius *om*, and that the force of inertia is applied at the centre—we shall obtain, successively,

$$y = r - r \cos (\alpha - 90)$$
$$y = r (1 - \sin \alpha)$$
$$v_y = \frac{dy}{dt} = - r \cos \alpha \frac{d\alpha}{dt}$$
$$j_y = \frac{d^2y}{dt^2} = r \sin \alpha \left(\frac{d\alpha}{dt}\right)^2$$
$$F_y = \frac{Q}{2g} . r \sin \alpha \left(\frac{N}{60}\right)$$
$$F_y = K'' . \sin \alpha.$$

We may assume this force to be equally distributed, half at each end of the connecting rod.

This calculation is only approximate, but quite sufficient to show what takes place.

We will neglect the variations in pressure at the connection between the piston and the connecting rod, and only consider the pressure on the crank pin.

Resolving the pressures into x and y, components tangential

and centripetal to the rotary motion of the head of the connecting rod, we get:

tangential component of $F_x = T_x = F_x \sin \alpha$;
tangential component of $F_y = T_y = F_y \cos \alpha$;
normal component of $F_x = N_x = F_x \cos \alpha$;
normal component of $F_y = N_y = F_y \sin \alpha$.

Substituting their values for F_x and F_y, we have

$$T_x = K' \cos \alpha \sin \alpha = \frac{K'}{2} \sin 2\alpha$$

$$T_y = K'' \sin \alpha \cos \alpha = \frac{K''}{2} \sin 2\alpha$$

$$N_x = K' \cos^2 \alpha$$
$$N_y = K'' \sin^2 \alpha.$$

Calling T the total tangential component and N the normal component, we find

$$T = T_x + T_y = \frac{K' + K''}{2} \sin 2\alpha$$

$$N = N_x + N_y = K' \cos^2 \alpha + K'' \sin^2 \alpha.$$

From these two equations we see that the tangential component has maximum value when $\alpha = 45$ degrees, and is zero when $\alpha = 0$ or $\alpha = 90$ degrees. The curve shown on Fig. 109 shows the variations of T as a function of α. This force is positive, and tends to impede the working of the motor during the first half of the forward stroke, and assists working during its second half.

On the other hand, the normal component N, shown by the curve on Fig. 110, has maximum value when $\alpha = 0$ and minimum value when $\alpha = 90$ degrees.

The magnitude and direction of this force at every instant is represented by the corresponding radius of the ellipse.

It follows, therefore, that the moving masses will sometimes raise the driving shaft from, and sometimes press it down on, its bearings, and that any pressure tangential to the head of the connecting rod will sometimes accelerate, and at other times retard, the rotation of the motor.

This will cause jarring and jolting if there is the slightest play between any parts of the motor. To prevent, as far as possible, the variations in the normal force N, it is necessary to employ engines with two cylinders, and to set the crank pins at 180 degrees to one another, so that the strains are always opposed in direction, and consequently always in equilibrium.

The stress at the beginning of each stroke, due to the motion of translation and represented by half the major axis of the ellipse in Fig. 110, does not necessarily entail a change in the direction of the pressure acting on the crank pin.

Another factor must be taken into consideration—the pressure of the gas on the piston.

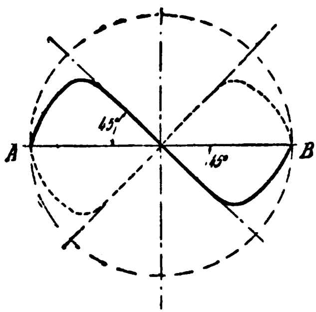


Fig. 109.

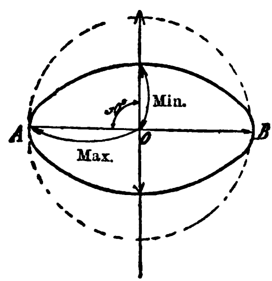


Fig. 110.

Take Fig. 111, and on the abcissa AB set up ordinates proportional in length to the pressure of gas on the piston. For an Otto-cyle motor we have the diagram shown by the curve 1, 2, 3, 4, 5, 6. During exhaust and admission of gas the line of pressures 5 4 and 4 5 will necessarily intersect the curve 1 7, which represents the variations of pressure due to the moving masses. Consequently, as this mass cannot be reduced to zero, the pressure on the crank pin will alter in direction.

It is better, however, to calculate the weight of the moving parts, so as to prevent the change of direction of the force

from taking place during the periods of explosion, expansion, and compression. The figure shows that to effect this the compression must be sufficient to exert a pressure at least equal to that of the moving masses at the end of the return stroke.

Fig. 112 is the diagram of a single-cycle engine. The force always changes direction during expulsion of gas, and admission of the latter must take place under a pressure at least equal to that due to the moving masses.

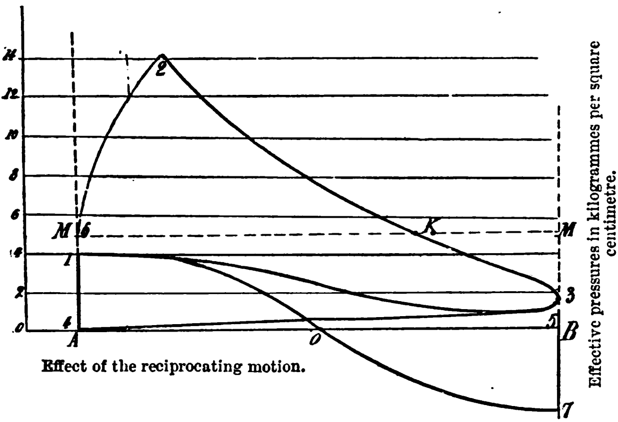


FIG. 111.

From what we have just seen regarding parts with reciprocating motion, it follows :

1st. That the motor must be balanced ; that is, must consist of two cylinders whose connecting rods are connected to crank pins set at 180 degrees to one another, so as to avoid excessive pressure on the bearings.

2nd. That the reciprocating parts must be as light as possible.

3rd. That compression must be at least equal to the maximum reaction of the moving parts. This can be found with the aid of the formulæ we have already given.

These conditions reduce, as far as possible, the change of direction of the force acting on the crank pin. As regards vibration transmitted to the car, the sudden increase of pressure due to the explosion of the gas is of much greater importance. It occurs, as we know, at the beginning of the stroke, and tends to strain the framework supporting the motor and to jolt the car. This framework, being elastic, will resume its normal shape, but the same stress will occur every other revolution. This kind of shock cannot be avoided

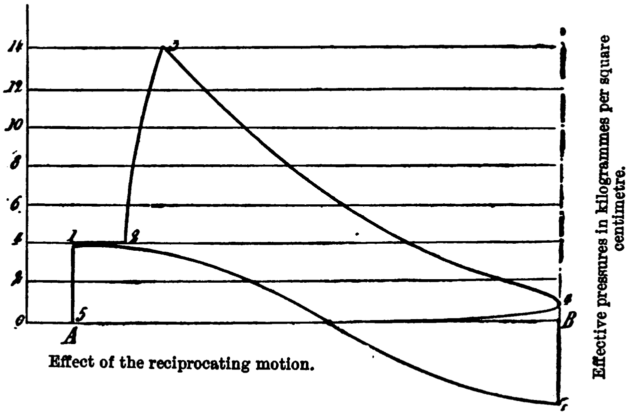


FIG. 112.

unless the pressure is considerably decreased at the time of explosion. This could be arrived at by increasing the length of the cylinder to prolong expansion, and by leaving a large quantity of inert gas in the latter at the time of explosion. Mr. Loyal has applied this principle to his motor described in Chapter IX.

Another method is to obtain a kind of boiler of hot gases under pressure similar to that described in connection with the Duryea car.

The motor must have a fairly large flywheel, so that the

work available during explosion and expansion shall not jerk the car. If the line MM' (Fig. 111) represent the mean ordinate proportional to the average work done by the motor, then the area $(M2K - M'K3)$, representing the excess work done during expansion, must be stored up by the flywheel without increasing the speed very much.

This storage of excess work is accomplished, therefore, by the heavy flywheel keyed to the shaft, assisted by the kinetic energy of the moving car.

Let ν be the velocity of translation of the car, M its mass, ν' the circumferential velocity of the flywheel, and M' its mass, the total kinetic energy will be expressed by

$$W = \frac{1}{2}(M\nu^2 + M'\nu'^2);$$

and if

$$\frac{\nu}{\nu'} = n,$$

we shall have

$$W = \frac{1}{2}\left(M\nu^2 + M'\frac{\nu^2}{n^2}\right),$$

whence

$$W = \frac{1}{2}\nu^2\left(M + \frac{M'}{n^2}\right).$$

If we only allow an acceleration of $\frac{\nu}{m}$ of the ordinary velocity, we shall obtain

$$\text{Work } (M2K - M'K3) = \frac{1}{2}\left(M + \frac{M'}{n^2}\right)\left(\nu + \frac{\nu}{m}\right)^2.$$

We can deduce the value of the mass M' for a flywheel of any given diameter by means of the above equation if the mass of the car, its ordinary velocity, and the ordinary velocity of the motor are known.

When the car is not running at its normal speed there will be jerks, so that to avoid them it will be better to calculate M' for a speed less than its average speed.

We will now close the examination of these rather theoretical conditions, which we have but merely sketched out. We have, in fact, entirely neglected the action of the springs of the car and that of its tyres. This action will regulate and deaden the jerks of the motor.

The small compass of this book will not allow us to enter into the theory of these phenomena, which even then would not throw any very precise light upon the subject.

APPENDICES.

I.

SIR DAVID SALOMONS' LETTER TO THE PRESS.

We think it may be interesting to reproduce the following letter, sent to the English Press by Sir David Salomons, President of the Self-Propelled Traffic Association, on the passing of the new 'Locomotives on Highways Bill.'

'After a long period of labour the "Locomotives on Highways Bill, 1896," has become an Act, and probably at no period in the history of the English Legislature has so liberal a measure been passed. Indeed, the President of the Local Government Board cannot be charged with a want of faith in humanity, believing, as he must do, that no abuses will follow the help he has so freely extended to the new movement. My object in requesting the publication of this letter is, on the one hand, to express the gratitude of all those I represent in this movement to the Government, to the permanent officials of the departments concerned, and to all others by whose labours and influence success has been obtained; and, on the other, to appeal to everyone interested in the movement, whether as manufacturers or users of motors, to do nothing on their part to abuse the freedom which has now been extended to them. It behoves everyone concerned to act with prudence and consideration; to avoid injury to the roads; to use every possible care not to frighten horses; to store no dangerous liquids thoughtlessly, which might endanger life or property; and to act generally with such discretion that it shall not be said in a year or two hence another Act must be passed to control those who have shown their inability to control themselves, or misused their privileges. There cannot be the slightest doubt in the mind of any reasonable man

that this Act will be productive of great changes, and that if all those who have an interest in modern progress will strive to improve self-propelled traffic, and those who avail themselves of its benefits will act fairly towards others having no direct interest in the movement, it will be giving the English nation an advantage which can hardly be overrated, and without entailing, as I hope and believe, a vestige of discomfort or annoyance on any individual.'

II.

THE AUTO-CAR BILL.

The Locomotives on Highways Bill, 1896.

As amended by the Standing Committee on Law, and entitled 'An Act to amend the Law with respect to the Use of Locomotives on Highways,' this Act now reads as follows:

Be it enacted by the Queen's most Excellent Majesty, by and with the advice and consent of the Lords Spiritual and Temporal, and Commons, in this present Parliament assembled, and by the authority of the same, as follows:

1. (1) The enactments mentioned in the schedule to this Act, and any other enactment restricting the use of locomotives on highways, and contained in any public, general, or local and personal Act in force at the passing of this Act, shall not apply to any vehicle propelled by mechanical power if it is under three tons in weight unladen, and is not used for the purpose of drawing more than one vehicle (such vehicle with its locomotive not to exceed in weight unladen four tons), and is so constructed that no smoke or visible vapour is emitted therefrom except from any temporary or accidental cause; and vehicles so exempted, whether locomotives or drawn by locomotives, are in this Act referred to as light locomotives.

Provided that—

(*a*) A county authority shall have power to make byelaws preventing or restricting the use of such locomotives upon any bridge where such authority are satisfied that such use would be attended with damage to the public, subject to an appeal to the Local Government Board by any person aggrieved by the exercise of the power.

(b) A light locomotive shall be deemed to be a carriage within the meaning of any Act of Parliament, whether public, general, or local, and of any rule, regulation, or byelaw made under any Act of Parliament, and, if used as a carriage of any particular class, shall be deemed to be a carriage of that class, and the law relating to carriages of that class shall apply accordingly.

(2) In calculating for the purposes of this Act the weight of a vehicle unladen, the weight of any water, fuel, or accumulators used for the purpose of propulsion shall not be included.

2. The keeping and use of petroleum or any other inflammable liquid or fuel for the purpose of light locomotives shall be subject to regulations made by a Secretary of State, and regulations so made shall have effect notwithstanding anything in the Petroleum Acts, 1871 to 1881, and breach of any such regulation may, on summary conviction, be punished by a fine not exceeding ten pounds.

3. (1) The Local Government Board may make regulations with respect to the use of light locomotives on highways, and their construction and other conditions under which they may be used, and a breach of any such regulations may be thereby made punishable by a fine not exceeding ten pounds, recoverable on summary conviction.

(2) Regulations under this section may, if the Local Government Board deem it necessary, be of a local nature, and limited in their application to a particular area.

4. The requirements of sub-section four of section twenty-eight of the Highways and Locomotives Amendment Act, 1878, may be from time to time varied by order of the Local Government Board.

5. In the application of this Act to Scotland a reference to the Secretary for Scotland shall be substituted for a reference to the Local Government Board.

6. In the application of this Act to Ireland a reference to the Local Government Board for Ireland shall be substituted for a reference to the Local Government Board.

7. This Act may be cited as the Locomotives on Highways Act, 1896.

ENACTMENTS WHICH ARE NOT TO APPLY TO LIGHT LOCOMOTIVES.

The Locomotives Act, 1861 (24 and 25 Vict. c. 70), except so much of section one as relates to tolls on locomotives, and sections seven and thirteen.

Section forty-one of the Thames Embankment Act, 1862 (25 and 26 Vict. c. 93).

The Locomotives Act, 1865 (28 and 29 Vict. c. 83).

The Locomotives Amendment (Scotland) Act, 1878 (41 and 42 Vict. c. 58).

Part II. of the Highways and Locomotives (Amendment) Act, 1878 (41 and 42 Vict. c. 77).

Section six of the Public Health (Ireland) Amendment Act, 1879 (42 and 43 Vict. c. 57).

III.

THE PARIS-MARSEILLES RACE, SEPTEMBER, 1896.[1]

This race was organised by the Automobile Club of France, and had been originally fixed to take place in June, but as many makers would not have been ready in time it was decided to postpone the race until September 24, 1896.

The total distance covered—Paris to Marseilles and back—was about 1,070 miles. The conditions of the race were different to those enforced in the Paris-Bordeaux race of 1895. No night travelling was allowed, the cars having to stop every evening at a settled halting-place, where a fresh start could be made the following morning. The road was divided into ten stages, as follows:—

1.	Paris to Auxerre	110 miles.
2.	Auxerre to Dijon	94 „
3.	Dijon to Lyons	123 „
4.	Lyons to Avignon	141 „
5.	Avignon to Marseilles	66 „
6.	Marseilles to Avignon	66 „
7.	Avignon to Lyons	141 „
8.	Lyons to Dijon	123 „
9.	Dijon to Auxerre	94 „
10.	Auxerre to Paris	110 „

Each stage corresponding to a day's journey. The hour of departure and arrival of each car was carefully noted every day, and the times employed on the stages were added together to decide the winner.

Over 3,000*l.* was subscribed for distribution as prize money.

The cars were divided into three classes for competition:—Class

[1] Summarised extract from the *Autocar*.

A, for cars with two, three, and four seats; Class A_2, for cars with over four seats; and Class B, for auto-cycles.

Fifty-two cars were originally entered for the race, but only thirty-two started. Of these, twenty-four were propelled by petroleum and only three by steam, the remaining five being petroleum tricycles.

The start took place at the Place d'Armes at Versailles in the presence of thousands of spectators.

The different parts of the carriages were sealed to prevent being changed along the route, and then the cars were sent off at intervals of a minute. The following are the names and order of starting of the competitors :—

No.	Name	Type of car	No. of seats	Motor employed	Power	Driver
32	Fisson	victoria	2	Benz	petroleum	M. Fisson
41	Delahaye	break	4	Delahaye	”	M. Archdeacon
29	Cie Parisienne des Voitures Automobiles	phaeton	4	Benz	”	M. Radloer
30	Cie Parisienne des Voitures Automobiles	vis-à-vis	4	”	”	M. Labouret
6	Panhard-Levassor	phaeton	4	Rotary	”	M. Mazade
44	Peugeot	”	2	Peugeot	”	M. Doriot
5	Panhard-Levassor	car	2	Rotary	”	M. Levassor
42	Delahaye	dog-cart	4	Delahaye	”	M. Delahaye
12	De Dion-Bouton	steam tractor	4	De Dion-Bouton	steam	Count de Dion
20	Bollée	vis-à-vis	4	Bollée	petroleum	M. Bollée
8	Panhard-Levassor	omnibus	4	Rotary	”	—
9	Lebrun	car	2	Daimler	”	M. Lebrun
26	Landry & Beyroux	cabriolet	2	—	”	M. Landry
45	Peugeot	car	2	Peugeot	”	—
28	Rossel	”	2	Daimler	”	M. Rossel
46	Chasseloup-Laubert	steam omnibus	4	Chasseloup Laubert	”	—
7	Panhard-Levassor	car	6	Rotary	”	—
24	Triouleyre	wagonette	6	Horizontal	”	—
25	”	—	2	”	”	—
10	De Dion-Bouton	break	5	De Dion-Bouton	steam	—
39	Michelin	Bollée tandem	2	Bollée	petroleum	—
21	Bollée	Bollée tandem	2	”	”	M. Bollée
47	Bollée	—	—	—	—	—
52	De Dion	tricycle	—	—	—	—
15	”	”	—	—	—	—
51	”	”	—	—	—	—
13	”	”	—	—	—	—
14	”	”	—	—	—	—
43	Rochet-Schneider	vis-à-vis	4	Rochet-Schneider	petroleum	—
37	Tissandier	car	2	—	—	M. Tissandier

A Bollée car and a Tenting car for four passengers were timed having started, although they had not reached Versailles, through some delay occurring.

The first stage of the journey was accomplished in excellent weather, and the first to arrive at Auxerre was a Bollée vehicle, which covered the distance at an average rate of about 20 miles an hour. The total number who completed the first stage were twenty-seven, five having given up owing to various causes.

The second stage was run under very trying conditions of weather, and only fifteen vehicles reached Dijon, the first four arrivals being all Panhard-Levassor cars. During the third stage rain fell heavily, and the roads were in a terrible condition. No. 6 Panhard-Levassor car arrived first at Lyons, and altogether fourteen reached destination. The fourth stage was run in better weather, and No. 46 Peugeot car arrived first at Avignon, followed by twelve other competitors. These thirteen competitors all reached Marseilles the following day, an exceedingly fast run on this stage being accomplished by No. 6 Panhard-Levassor car.

The start on the return journey was made on September 29 at midday. Some of the competitors having arrived overnight, sixteen were able to start, of whom fifteen arrived at Avignon, sixth stage. The seventh stage was run in wind and rain, No. 6 Panhard-Levassor arriving first at Lyons. This car again came in first at Dijon, the end of the eighth stage, the run being accomplished against a strong head wind, and it was also first at the end of the ninth stage, and finally won the race, having accomplished the journey to Marseilles and back in slightly under 68 hours, representing roughly an average speed of sixteen miles an hour.

No. 6 Panhard-Levassor car was therefore awarded the first prize in Class A, the prize in Class A_2 being won by No. 46 Peugeot car, and that in Class B (auto-cycle) by No. 18 Dion tricycle.

The inevitable accidents that occurred along the route were mainly due to outside causes, and not to any inherent defects in the cars themselves. Some of the cars were upset by dogs, and others by fallen trees blown across the road by the gale. One was charged by a bull, which evidently objected to self-propelled traffic. The cars, however, that returned to Paris were all in good condition, considering the distance travelled, and the race was deemed a very successful one, having fulfilled all expectations.

IV.

TABLE OF FRENCH AND ENGLISH EQUIVALENTS.

(*Note by Translator.*)

In converting the dimensions of the metric system, used in the French original, into English dimensions, the following equivalents have been adopted:

1 kilomètre = 0·62 mile.
1 mètre = 3·28 feet.
1 centimètre = 0·394 inch.
1 millimètre = 0·039 inch.
1 square mètre = 10·764 square feet.
1 French ton (1,000 kgs) = 1 English ton (2,240 lbs.).[1]
1 kilogramme = 2·2 lbs.
1 „ per sq. mètre = 0·205 lb. per sq. ft.
1 „ „ centimètre = 14·22 lbs. per sq. in.
1 „ „ millimètre = 0·635 ton per sq. in.
1 „ per kilomètre = 3·5 lbs. per mile.
1 gramme = 0·564 dram (avoirdupois).
1 atmosphere = 1 kilogramme per sq. cm. = 14·22 lbs. per sq. in.
1 French horse-power (75 kilogrammètres per second) = 1 English horse-power[1] (33,000 ft.-lbs. per minute).
1 litre = { 0·22 gallon. / 61·027 cub. ins. }

$$\text{Centigrade} = \frac{(\text{Fahrenheit} - 32)\ 5}{9}$$

$$\text{Fahrenheit} = \frac{\text{Centigrade} \times 9}{5} + 32$$

Increment of increase of original volume of gas per degree of temperature Centigrade = $\frac{1}{273}$.

Increment of increase of original volume of gas per degree of temperature Fahrenheit = $\frac{1}{493}$.

Absolute zero temperature = − 273° Centigrade.
„ „ „ = − 461° Fahrenheit.

A *calorie*, or thermal unit, is the amount of heat required to raise the temperature of 1 gramme of water from 0° C. to 1° C. The British thermal unit or Joule's mechanical equivalent of heat is equivalent to 772 foot-pounds, required to raise 1 lb. of water from 60° F. to 61° F.

[1] These are not quite exact, but sufficiently correct for our purpose.

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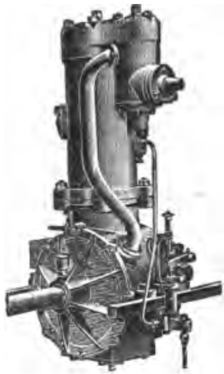

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